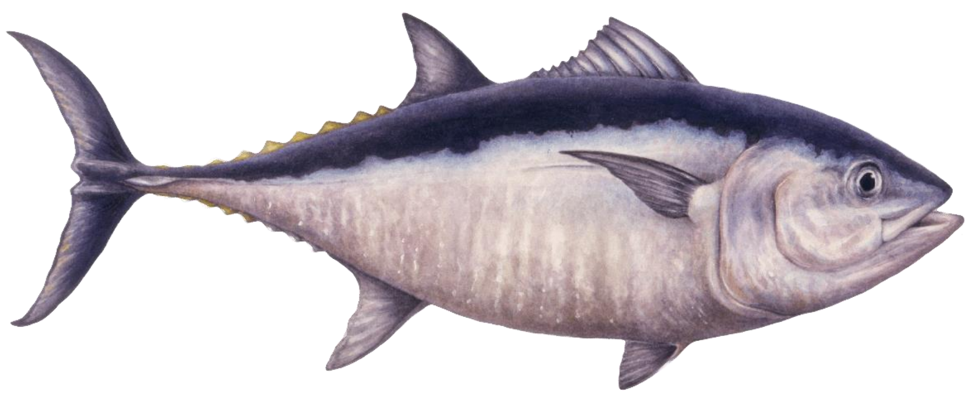
Monterey Bay Aquarium
Seafood Watch®

Southern Bluefin Tuna

Thunnus maccoyii



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Australia

Net Pens

Aquaculture Standard Version A2

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Final Seafood Recommendation

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.39	YELLOW	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	9.00	GREEN	NO
C4 Chemicals	6.00	YELLOW	NO
C5 Feed	0.00	CRITICAL	YES
C6 Escapes	10.00	GREEN	NO
C7 Disease	6.00	YELLOW	NO
C8 Source	0.00	RED	
C9X Wildlife mortalities	–5.00	YELLOW	NO
C10X Introduced species escape	0.00	GREEN	
Total	**40.39**		
Final score	**5.05**		

OVERALL RANKING

Final Score	5.05
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES

FINAL RANK
RED

Scoring note –scores range from 0 to 10 where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Color ranks: red = 0 to 3.33, yellow = 3.34 to 6.66, green = 6.66 to 10. Criteria 9X and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects very poor performance. Two or more red criteria trigger a red final result.

Summary

The final numerical score for net pen farming of southern bluefin tuna in Australia is 5.05 out of 10. The presence of two Red criteria (Feed, Source of Stock) automatically results in an overall Red recommendation of “Avoid.”

Executive Summary

This assessment was originally published in December 2016 and reviewed for any significant changes in February 2021. Please see Appendix 2 for details of review.

Southern bluefin tuna *(Thunnus maccoyii)* farming in Australia is a capture-based aquaculture practice that uses wild-caught individuals as captive farm stock. Southern bluefin tuna propagation has been attempted by one South Australian aquaculture company, but survival has remained inadequate for commercial-scale hatchery production, and further efforts were scaled back in 2013 to maintaining broodstock only. Although hatchery-reared (i.e., fully farm-raised) Pacific bluefin *(Thunnus orientalis)* are being produced within Japan and sent to domestic markets on a regular basis, the majority of farmed bluefin tuna worldwide result from wild capture in Australia, Japan, the Mediterranean, and Mexico. This farming practice clearly overlaps with the wild fisheries sector, and industry management is influenced by both aquaculture and wild fishery regulations.

Though there has been interest in developing southern bluefin tuna farms in other Australian states, southern bluefin aquaculture currently occurs only in net pens (regarded as “pontoons” in Australia) off Port Lincoln, lower Spencer Gulf, South Australia (SA). This siting reflects the environmental suitability of the area for southern bluefin grow-out (i.e., the location is within their natural range) and the ready availability of wild juvenile stock (< 4 years old) during their annual feeding migration off the southwest coast of Australia. Southern bluefin tuna farming involves the capture of wild stocks of juvenile bluefin from December to early April in the Great Australian Bight, west of the Eyre Peninsula in South Australia, and the towing of these fish to farm sites 10–20 km seaward of Port Lincoln, SA. Initially weighing 15–20 kg, the juvenile bluefin are reared over 4–8 months, depending on the marketing strategies of individual companies, before reaching 30–40 kg at harvest between July and September. Under current southern bluefin farming methods in SA, all captive tuna are harvested during the same season in which they are caught, and a subsequent 1-year minimum fallow period is required under the current management regime before individual net pen sites are allowed to be reoccupied. During the 2013–14 season, Australia produced an estimated 7,544 t of farmed southern bluefin tuna.

Largely because of the establishment of the Fisheries Research and Development Corporation (FRDC) Southern Bluefin Tuna Aquaculture Subprogram between 1997 and 2008, and the Cooperative Research Centre for the Sustainable Aquaculture of Finfish (Aquafin CRC program) between 2001 and 2008, data availability and accessibility regarding the environmental impacts of bluefin tuna farming and related management measures can be considered above average. Aquafin CRC reports include data on waste management, husbandry practices, nutrition and feed development, southern bluefin health, and wildlife interactions. In addition to Aquafin CRC reports, production statistics are published annually by the national Department of Agriculture, and public disclosure processes have been implemented for both aquaculture zone policy development and lease/license assessments under the South Australian Aquaculture Act 2001.

Aquafin CRC reports are published online and are accessible to the general public; nonetheless, it is widely accepted that these industry reports are not independent of shareholder influence. Other important data limitations in the literature include reporting exemptions for some chemicals, wildlife mortality rates, disease impacts on wild counterparts, and environmental monitoring data by SARDI. Under these conditions, there is considered to be an overall moderate level of data quality and availability to assess the Australian bluefin tuna farming industry's operations and impacts under Seafood Watch criteria. The Criterion 1 - Data score is 6.39 out of 10.

For southern bluefin tuna farms in Australia, all discharged effluent, consisting of uneaten baitfish and solid/soluble waste, is released untreated from the net pens into the surrounding environment. Monitoring results show that southern bluefin tuna farms typically do not impact the chemical or biological characteristics of the water column. Although benthic deposition can be significant, it is quickly metabolized by the marine environment or exported out of the system by strong hydrodynamic regimes. This reflects high nutrient influx rates but a low, localized accumulation of waste and minimal impacts that are considered temporary. When combined with best management feeding practices, extended fallow periods, and current low stocking densities (2–4 kg m^{-3}), the regional effect of southern bluefin farms is demonstrably unlikely to cause substantial changes to the overall nutrient loading status of Australia's coastal waters. Furthermore, robust and consistent regulatory measures exist throughout the industry to monitor both site-specific and cumulative impacts associated with southern bluefin farming. Overall, the lack of significant local or regional cumulative impacts beyond the immediate vicinity of Australian southern bluefin tuna farms result in a final Criterion 2 - Effluent score of 8 out of 10.

In southern bluefin tuna farming, the floating net pens have a minimal direct habitat impact, and benthic impacts produced by individual farms are generally limited to an area directly beneath the farm site. Given the relatively confined nature of benthic impacts, the potential for cumulative impacts from adjacent sites or from the industry's total impact area is considered low. For Habitat Conversion and Function (Factor 3.1), the compositional characteristics of tuna waste, the hydrographic setting of the Tuna Farming Zones, and the operational factors employed by the tuna farming industry result in low accumulations of organic matter in the sediments beneath tuna net pens and a score of 9 out of 10. The implementation of aquaculture zones in SA includes a site selection process that ensures the avoidance of critical habitats and a robust review of the ecological appropriateness of the region for southern bluefin farming. Fallowing requirements by the SA government largely lead to recovery and are considered successful at preventing the accumulation of solid waste beneath tuna net pens. Furthermore, public participation and transparency is widely implemented in Australia, with well-established processes to ensure that environmental considerations are addressed during both lease/license and aquaculture zone development. For Habitat and Farm Siting Management (Factor 3.2), the effective habitat regulations and the subsequent absence of significant benthic impacts beneath active tuna farm sites results in a score of 9 out of 10. When combined, these conditions result in an overall Criterion 3 - Habitat score of 9 out of 10, indicating a "low" level of concern for habitat impacts.

Currently, praziquantel (an anti-parasitic blood fluke treatment) represents the only documented chemical therapeutant used in southern bluefin tuna farming. Although all therapeutic, prophylactic, or antifouling substances used in the course of aquaculture must be approved by the Australian Pesticides and Veterinary Medicines Authority (APVMA) in Australia, the SA government permits exemptions from reporting for some chemicals under human and animal health considerations under the APVMA Act. Overall, southern bluefin is a culture species that has had a demonstrably low need for chemical inputs, but specific data are currently limited. These conditions result in a moderate level of concern under Seafood Watch criteria and a Criterion 4 - Chemical Use score of 6 out of 10.

Although formulated pellet feeds for other finfish are available in Australia, southern bluefin tuna farms rely solely on the use of whole, wild baitfish for feed due to the lower feeding costs. Unlike almost all other aquaculture industries that are focused on growing their farmed stocks, the primary goal of Australian tuna operations is to increase the tuna's fat content for market desirability. Therefore, the feed conversion ratio is typically high. Reported economic feed conversion ratios (eFCR) vary from 10 to 15 for farming juveniles. The exclusive use of whole feedfish means that the Fish In to Fish Out ratio (FIFO) is the same as the eFCR and produces a critically high FI:FO ratio (a simple measure of wild fish use) and a score of 0 out of 10. In the wild, tuna also consume baitfish, but do so as part of a complex natural foodweb and ecosystem. The extraction of these two ecosystem components (i.e., the tuna and the baitfish) and their use as inputs in an artificial farming system does not enable them to provide the same ecosystem services that they would in the wild. Local Australian sardine, local redbait, and California sardine represent the most common feed ingredients, but a variety of other baitfish species are utilized as feed. A precautionary Source Fishery Sustainability score of –4 out of –10 was applied to Factor 5.1 (Wild Fish Use), producing a final adjusted score that remained 0 out of 10. Furthermore, a net protein loss greater than 90% and the presence of a significant feed footprint (90.70 ha per ton of farmed fish) represent additional environmental concerns. Overall, the absence of by-products or non-edible processing ingredients as alternative sources of feed protein and the highly inefficient conversion of feed into harvestable fish result in a critical Criterion 5 - Feed score of 0 out of 10.

For net pen aquaculture, there is an inherent risk of escape from catastrophic losses or more chronic "leakage." Given that farmed tuna are the product of capture-based aquaculture and that captive tuna originate from Australian waters, the risk of ecological (i.e., competitive and/or genetic) impact of escaped tuna on other wild species or wild counterparts is considered to be minimal. The resulting Criterion 6 - Escape score is therefore 10 out of 10.

Although southern bluefin tuna farms are strongly associated with high pathogen prevalence and diversity, disease-related mortality in Australia is generally low because of a substantial fallow period, low stocking densities, and the stocking of large immuno-competent tuna. Disease management training and best management protocols have been developed jointly by the tuna farming industry and government research campaigns. There is currently no clear evidence that pathogens or parasites within southern bluefin farms are causing significant population declines in wild tuna stocks; however, the prevalence of pathogens within farm sites, the open nature of tuna net pens, and the close proximity of farm sites to southern bluefin migration routes warrant a low to moderate level of concern for potential disease transfer between farmed and wild species. These conditions result in a precautionary Criterion 7 - Disease score of 6 out of 10.

Australian bluefin tuna farms are considered to be 100% reliant on critically endangered wild tuna populations due to the industry-wide dependence on wild-caught individuals for farm stock. Thus, the Criterion 8 - Source of Stock score is 0 out of 10.

Seals, sharks, and dolphins are the primary wildlife species interacting with bluefin tuna farms in Australia. For seabirds and protected marine vertebrates, tuna farmers must employ non-lethal methods to deter predators, as required by national and state legislation. Although there are predator-interaction reporting obligations for tuna farmers, exceptionally little robust data exist on the tuna farming industry's impact on seal, sea lion, and shark populations. The lack of statistical data available for farm-related wildlife mortalities, the endangered status of shark and sea lion species, and historic reports of these species being killed by industry workers result in a precautionary approach to scoring this criterion. The penalty score for Exceptional Criterion 9X - Wildlife Mortalities is –5 out of –10.

In Australian southern bluefin tuna farming, wild tuna are captured and transported to net pens within the same waterbody, so the unintentional introduction of non-native species does not occur. Generally, there is some risk of non-native species introduction associated with open exchange net pens, but the exclusive use of native tuna (0% reliance on international or trans-waterbody live animal shipments) results in a Criterion 10X - Escape of unintentionally introduced species final score of 0 out of –10.

In summary, the final numerical score for net pen farming of southern bluefin tuna in Australia is 5.05 out 10. This moderate numerical score and two Red criteria (Feed, Source of Stock) result in an overall Red recommendation of "Avoid."

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Species Overview

Southern bluefin tuna *(Thunnus maccoyii)* is one of 13 species of tuna in the Scombridae family. Its closest relative is the northern bluefin tuna *(Thunnus thynnus)*. Southern bluefin is a commercially important fish distributed widely in temperate regions of the Southern Hemisphere between 30° and 50° S in the Pacific, Indian, and Atlantic Oceans (Clean Seas Tuna 2005) (Aiken et al. 2006). As a large, pelagic marine fish, southern bluefin tuna reaches a maximum weight of ≈260 kg (572 lbs) and a maximum length of ≈245 cm (8 ft) (Blue Ocean Institute n.d.) (Barneveld et al. 1997) (Flood et al. 2012). Well known for its distinct physiology, bluefin tuna is an endothermic fish species possessing the unique ability to maintain internal temperatures through metabolic processes (Korsmeyer and Dewar 2001). An obligatory ram ventilator, bluefin must swim constantly to maintain a continuous flow of water over its gills and is continually in search of food to maintain this high metabolism (Patterson et al. 2008). Tuna are opportunistic feeders and consume a wide range of prey, often rapidly and in quantity during feeding migrations from the Indian Ocean to the Southern Ocean off the coast of Australia (Barneveld et al. 1997) (Padula et al. 2008) (Pecl et al. 2011). Juvenile tuna generally prey on fish, squid, and crustaceans, whereas mature tuna, which are associated with the top of the trophic food web, primarily feed on pelagic fishes. Southern bluefin matures somewhere between ages 8 and 14 and can live over 40 years (Blue Ocean Institute n.d.) (Barneveld et al. 1997) (Clean Seas Tuna 2005) (Pecl et al. 2011) (Flood et al. 2012).

Although the distribution of southern bluefin in southern temperate waters is circumpolar, only a single highly migratory biological stock exists that breeds at spawning grounds located between northwest Australia and south Java, Indonesia (Figure 1) (Pecl et al. 2011) (Flood et al. 2012). Southern bluefin tuna is a broadcast spawner and the annual spawning season lasts from September to April (Blue Ocean Institute n.d.) (Clean Seas Tuna 2005) (Pecl et al. 2011). From December to April, schools of juvenile fish (1–4 years old) congregate seasonally and move southward from the northeast Indian Ocean toward major feeding grounds in surface waters off the state of South Australia, particularly around the Great Australian Bight (Barneveld et al. 1997) (Clean Seas Tuna 2005) (Cardia and Lovatelli 2007) (Padula et al. 2008) (Kirchhoff et al.

2011) (Kirchhoff et al. 2011b) (Georgeson et al. 2014). These congregations of surface-schooling juvenile bluefin have made them vulnerable to fishing pressure for decades (Blue Ocean Institute n.d.).

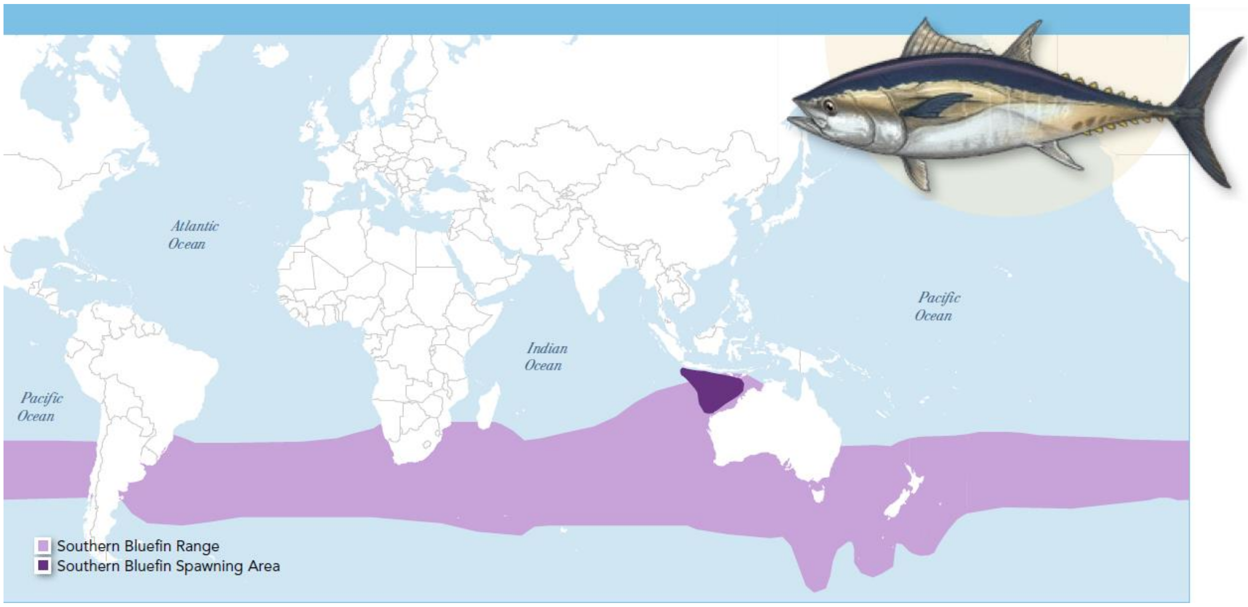

Fig. 1. Home range and spawning area of southern bluefin tuna (Source: Boustany 2011).

Production system

A standard holding net pen consists of large, single or double circular rings made from high-density polyethylene plastic, usually 30–50 m in diameter (Cardia and Lovatelli 2007) (Goldsworthy et al. 2009). A net, generally 150–200 mm in mesh size, is attached to the floating rings and has sides that maintain a distance of 5 m above the sea floor (15–20 m net depth) (Cardia and Lovatelli 2007) (Goldsworthy et al. 2009). Initially, predator nets were widely used to keep sharks and seals away from the tuna, but their use has been discontinued since the mid- to late 1990s due to widespread entanglement (Tanner 2007). The industry has 130–150 pens, each stocking up to 2,200 bluefin within a season (Fernandes et al. 2007), but farmers are required to maintain a very low stocking density of 2–4 kg m^{-3} (≈1,600 bluefin) (Nowak et al. 2003) (Tanner 2007) (Clarke and Ham 2008) (pers. comm., ASBTIA 5/31/2015). Tuna net pens are typically cleaned once every 6 months (Hellio and Yebra 2009). Juvenile southern bluefin are reared for 4–8 months (Nowak et al. 2003) (Clean Seas Tuna 2005) (Aiken et al. 2006) (Cardia and Lovatelli 2007) (Díaz López and Bernal Shirai 2007) (Fernandes et al. 2007) (Tanner 2007) (Clarke and Ham 2008) (Kirchhoff et al. 2011) (Kirchhoff et al. 2011b) (Leef et al. 2012) (PIRSA 2013) with most fish doubling in weight (Clarke and Ham 2008).

Fisheries information

Southern bluefin has been intensely targeted by fisheries from a number of different nations both on the high seas and within the exclusive economic zones of Australia, New Zealand, Indonesia, and South Africa, and commercial catches were very high in the early years of the fishery before declining steadily in the early 1950s (Flood et al. 2012) (Georgeson et al. 2014). In the absence of any harvest limits, worldwide catches reached a peak of 55,200 metric tons (MT) in 1969. In response to declining catches, the three primary nations fishing for southern bluefin (Japan, Australia, and New Zealand) began to apply catch quotas in 1985. In 1994, these voluntary arrangements were formalized with the signing of the Convention for the Conservation of Southern Bluefin Tuna, and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) has since managed the fishery internationally (Blue Ocean Institute n.d.) (Miyake et al. 2004). The Republic of Korea (2001) and Indonesia (2008) became members of the CCSBT, and Taiwan (2002), the Philippines (2004), South Africa (2006), and the European Union (2006) joined as Cooperating Non-Members (www.ccsbt.org).

Despite the implementation of the CCSBT quota system, southern bluefin tuna was listed as "Critically Endangered" by the International Union for Conservation of Nature (IUCN) in 1996, and relisted as "Critically Endangered" in 2009 based on a CCSBT southern bluefin stock assessment indicating an 85.4% decline in spawning stock biomass from 1973–2009 (Collette et al. 2011). In 2011, the CCSBT adopted a harvest control strategy, the Bali Management Procedure, which established global total allowable catch (TAC) guidelines to rebuild southern bluefin stocks to 20% of the original spawning stock biomass with 70% probability by 2035 (CCSBT 2013) (Georgeson et al. 2014). Given the current status of the original spawning stock biomass (only 3%–7% remaining), the Australian quota was initially reduced to 4,270 MT in 2011, but has since increased to 5,193 MT in 2014 (41.7% of the global TAC) (Georgeson et al. 2014) (http://www.ccsbt.org/site/conservation_and_management.php) (accessed Nov. 2014). Although recent trends in recruitment appear more positive than in previous assessments, measurable improvements in spawning stock biomass were not detected in 2012 (Flood et al. 2012), and as of 2014, the spawning stock biomass of southern bluefin tuna remains at a very low level.

There has been some improvement since the 2011 stock assessment, but fishing mortality is well below the level required to produce maximum sustainable yield (MSY).[1] Thus, the stock remains classified as Overfished by the Fisheries Research and Development Corporation (FRDC) and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES).

Southern bluefin tuna aquaculture in Australia

The southern bluefin tuna farming industry began in South Australia as a planned response to declining catches and the subsequent quota reductions of wild southern bluefin (Barneveld et al. 1997) (Tanner and Volkman 2009). As it became increasingly difficult for the Port Lincoln tuna fishing community to make a profit from canned tuna sold on the domestic market, the large reduction in tuna supply prompted a move from canning to value-adding through farming, with a focus on the Japanese sashimi market (Cardia and Lovatelli 2007) (Flood et al. 2012). By enhancing the weight and flesh quality of juvenile southern bluefin through farming, the South Australia product became viable for the Japanese market while allowing the tuna industry to

[1]https://www.ccsbt.org/sites/ccsbt.org/files/userfiles/file/docs_english/meetings/meeting_reports/ccsbt_22/report_of_CCSBT22.pdf

continue operating under heavily reduced quotas (Barneveld et al. 1997). The first experimental tuna farms were established in Boston Bay, Port Lincoln in 1991 by the Japanese Overseas Fishery Cooperation Foundation, the South Australian Government, and the Tuna Boat Owners Association of South Australia (now known as the Australian Southern Bluefin Tuna Industry Association, or ASBTIA) with funding from the Australian Fisheries Research and Development Corporation (FRDC) (Aiken et al. 2006) (Cardia and Lovatelli 2007) (Díaz López and Bernal Shirai 2007) (Tanner 2007) (Padula et al. 2008) (Kirchhoff et al. 2011) (pers. comm., ASBTIA 2015).

In April 1996, the remnants of tropical cyclone Olivia traveled southeast over the Great Australian Bight and passed over Port Lincoln, producing strong northeasterly winds for about 2 hours. These conditions produced waves with sufficient energy to lift fine organic sediment from the sea floor into suspension (Petrusevics 1996) (Grzechnik 2000). In combination with a dodge tide, these sediments coated the gills of the fish and may have contributed to a decrease in the dissolved oxygen in the water (Clarke 1996). The result was the death of over 1,700 MT of tuna, which constituted approximately 75% of the farmed stock at the time (Grzechnik 2000) (Nowak et al. 2003). Since this event, all tuna farms have been transferred to two large offshore areas called Sectors of the Lower Eyre Peninsula Tuna Farming Zone (TFZ) (pers. comm., ASBTIA 2015) according to Aquaculture Policy 2013 (Zones—Lower Eyre Peninsula). Currently located in waters seaward of Boston Island, tuna farms are now primarily 4–16 nm (8–30 km) offshore in a deeper, more exposed, and well flushed (2–20 day flushing time) open-water system (with one tuna farm located 50 km outside of Boston Island) (Fernandes et al. 2007) (Tanner and Volkman 2009) (Gaylard et al. 2013) (Kirchhoff et al. 2011) (Pecl et al. 2011) (pers. comm., Anonymous (b) 2015).

Since 2002, there has been a reduction and consolidation of farming companies because of the increased volume of farmed Atlantic and Pacific bluefin from the Mediterranean and Mexico (Clarke and Ham 2008) and the substantial decrease in allocated TAC quotas in 2011 (i.e., Bali Procedure). Though 40 southern bluefin tuna farming licenses were issued in 2009 (Pecl et al. 2011), the current commercial southern bluefin aquaculture industry comprises 18 licenses operated by 14 companies, with a maximum farm stocking capacity of 13,122 MT (Table 1) (http://www.ccsbt.org/site/authorised_farms.php, last accessed October, 2014).

	Company	Webpage	Sites	Farm stocking capacity
1	Australian Fishing Enterprises Pty Ltd	http://www.afe.net.au	4	2406
2	Australian Tuna Fisheries Pty Ltd	http://www.stehrgroup.net/incorporates.htm	1	731
3	Blaslov Fishing Pty Ltd	http://www.blaslovfishing.com.au	1	438
4	Clean Seas Tuna Ltd	http://www.stehrgroup.net/incorporates.htm	3	196
5	Dinko Tuna Farms Pty Ltd	http://www.lukinfisheries.com.au/tuna.htm	3	798
6	Eyre Tuna Pty Ltd	https://www.facebook.com/Eyre.Tuna	1	378
7	KIS Tuna Pty Ltd	http://www.kistuna.com.au	11	1398
8	Lucky's Fishing Pty Ltd	-	1	162
9	Marnikol Fisheries Pty Ltd	-	3	564
10	Sams Sea Farm Pty Ltd	http://www.afe.net.au/samstuna	11	3060
11	Sarin Marine Farm Pty Ltd	http://www.smf.net.au	3	840
12	Stehr, M. A.	-	1	90
13	Sekol Farmed Tuna Pty Ltd	http://www.sekol.jp/contents/home?language=english	1	366
14	Tony's Tuna International Pty Ltd	http://www.tonystuna.com.au	5	1695

Table 1: Southern bluefin tuna farms and capacity (t) in Australia (Source: http://www.ccsbt.org/site/authorised_farms.php).

Since 1999, more than 95% of the total wild quota has been farmed (Nowak et al. 2003) (Fernandes et al. 2007) (Clarke and Ham 2008) (Tanner and Volkman 2009) (Pecl et al. 2011) (Flood et al. 2012) (Skirtun et al. 2013) (AFMA 2013) (Georgeson et al. 2014) (Stephan and Hobsbawn 2014). Recently, the rise in production and value of the industry has leveled off and even declined as the full available quota has been used for farm production (Tanner 2007) (pers. comm., ASBTIA 2015). Southern bluefin propagation has been attempted by a single private South Australian company, Clean Seas Tuna Ltd., but survival has remained inadequate for commercial-scale hatchery production (pers. comm., PIRSA 2015). Given that the most successful outcome has been the production of larvae, with some fish being raised to 30–40 cm in length (Pecl et al. 2011), Clean Seas scaled back its Tuna Propagation Research Program in 2013 and now only maintains broodstock for the short to medium term (pers. comm., Anonymous (b) 2015). Further research and development for this project has been deferred to the Seafood CRC and FRDC (Clean Seas Tuna 2014).

After the development of tuna farming in South Australia, a large increase in fisheries efficiency and capacity occurred in the local tuna sector, with the purse seining fleet converted almost entirely into being a tuna provider for farm production (> 96%) (pers. comm., ASBTIA 2015). As a selective fishing method, purse seining is assisted by aerial spotting planes to locate schools of southern bluefin, allowing uniformly sized fish to be targeted (AFMA 2007) (AFE 2011) (AFMA 2013) (ASBTIA 2014). Purse seiners are the exclusive supplier to the tuna farming industry. This method usually involves two vessels and a spotter plane working together. When a school of southern bluefin is sighted from the air, the "chum" vessel distracts the school with bait while the purse seine boat encircles the school with the net (Clean Seas Tuna 2005). After the tuna are captured, they are transferred through underwater raceways to a specialized tow cage, then transported at 1–2 kt or less to net pen farm sites (i.e., up to 500 km over 10–20 days) (Cardia and Lovatelli 2007) (Goldsworthy et al. 2009) (Kirchhoff et al. 2011) (AFMA 2013). Individual companies may farm fish from any number of different tows, which may arrive at the grow-out site at different times (Kirchhoff et al. 2011b). The annual bluefin tuna purse seine season currently runs from December to February, and marketable tuna are harvested from net pens from July to September, with most shipped at ultra-low temperatures (–65°C) (Nowak et al. 2003) (Fernandes et al. 2007) (Clarke and Ham 2008) (Goldsworthy et al. 2009) (pers. comm., ASBTIA 2015).

Unlike other types of marine aquaculture, an important objective of fattening operations is not just to increase biomass, but to provide bluefin tuna markets with the desired flesh quality required for sushi and sashimi (high fat content). Juvenile bluefin (< 4 years old) weighing an average of 15–20 kg are caught from December to April each year and are harvested after 4–8 months of rearing, reaching a suitable quality and marketable size between 30 and 40 kg (Nowak et al. 2003) (Clean Seas Tuna 2005) (Aiken et al. 2006) (Cardia and Lovatelli 2007) (Díaz López and Bernal Shirai 2007) (Fernandes et al. 2007) (Tanner 2007) (Clarke and Ham 2008) (Kirchhoff et al. 2011) (Kirchhoff et al. 2011b) (Pecl et al. 2011) (Leef et al. 2012) (PIRSA 2013) (pers. comm., ASBTIA 2015). Long-term holding trials (18 months) have shown that weight gain and feed conversion ratio (FCR) were significantly compromised after the condition factor (a measure of overall health) of farmed tuna plateaued at 21.5 (Aquafin CRC 2008). Harvested juvenile tuna do not obtain the highest price in the Japanese market, but maintaining them any longer involves substantial problems with feeding and growth during the extended season and is not practiced due to poor cost-benefit results (Glencross et al. 2002) (Aquafin CRC 2008) (pers. comm., Anonymous (b) 2015).

Farmed southern bluefin production statistics

Currently, Australia is the only country farming southern bluefin tuna, with all farmed production coming from the state of South Australia (Fernandes et al. 2007) (Clarke and Ham 2008) (Kirchhoff et al. 2011) (Skirtun et al. 2013) (Stephan and Hobsbawn 2014) (pers. comm., ASBTIA 2015). Southern bluefin production statistics are published annually in Australian Fisheries Statistics by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), and also in an annual Economic Report on South Australian Aquaculture by EconSearch Pty Ltd for PIRSA. Since 2001, the growth of the tuna farming industry has leveled off due to utilization of almost the entire available quota (Clarke et al. 2005). Approximately 250,000 to 300,000 southern bluefin are farmed annually (pers. comm., ASBTIA 2015), producing approximately 7,700 MT per annum over the last 5 years.

Farm production of southern bluefin is constrained by the legal limits on wild southern bluefin through fisheries regulations. Since 1994, the global southern bluefin fishery has been managed by the CCSBT under the Convention for the Conservation of Southern Bluefin Tuna 1994 (Georgeson et al. 2014). The CCSBT adopted a harvest control strategy in 2011 (Bali Procedure) in which global TAC guidelines were established to rebuild current southern bluefin tuna stocks to 20% of the original spawning stock biomass by 2035 with 70% certainty (CCSBT 2013). These global TACs are set based on a Harvest Control Rule (precautionary TACs based on juvenile surveys and catch per unit effort [CPUE]), in which stock assessments are undertaken every 3 years. Although southern bluefin fishing mortality is currently below the maximum sustainable yield (ISSF 2015), there remains substantial uncertainty about the level of recovery and unaccounted catch mortality, and its potential impact on stock availability for southern bluefin tuna farming in Australia (Georgeson et al. 2014).

Currently, 14 licensed farm sites in the TFZ maintain a maximum potential capacity of 13,122 MT. This quantity is ≈53% of the max capacity allowed (24,860 MT) under the TFZ's current Aquaculture Policy (PIRSA 2013b). According to the latest statistics forecasted by ASBTIA, Australia produced 7,544 MT of farmed southern bluefin during the 2013–14 season (pers. comm., Anonymous 2015).

PIRSA Fisheries and Aquaculture has indicated that it intends to develop a number of new aquaculture zones in South Australia over the next 5 years, as well as revisit earlier assumptions of carrying capacity estimates developed by Tanner et al. (2007), in order to meet the anticipated expansion of the aquaculture industry within South Australia (Middleton et al. 2013). Southern bluefin tuna is the most valuable fishery species produced in South Australia (63% of aquaculture production by value), and currently represents the second-largest aquaculture finfish species produced in Australia, after Atlantic salmon (Fernandes et al. 2007) (Tanner 2007) (Skirtun et al. 2013) (Georgeson et al. 2014) (Stephan and Hobsbawn 2014).

Import and export sources and statistics

Since its inception, nearly all southern bluefin aquaculture production has been exported to Japan (Clean Seas Tuna 2005) (Padula et al. 2008) (Clarke and Ham 2008) (Georgeson et al. 2014). Because of bluefin's large size and the color, texture, and high fat content of its meat, it is the most sought-after species for sashimi. With each fish currently valued at approximately AUD 500 (FRDC 2014), the Japanese preference for southern bluefin is second only to northern bluefin *(Thunnus thynnus)* (Ottolenghi 2004) (Clarke et al. 2005) (Clarke and Ham 2008).

Farmed southern bluefin sold in Japan are concentrated in the hands of 5–10 Japanese trading houses; most notably, those at the Tsukiji Fish Market in Tokyo. Annual consumption of bluefin tuna in Japan is approximately 50,000 MT per year, of which farmed southern bluefin have comprised 4%–15% in recent years (Scott et al. 2012) (Skirtun et al. 2013) (pers. comm., ASBTIA 2015). Although 99% of global market demand for farmed southern bluefin comes from Japan, important markets are emerging in the United States, Europe, and southeast Asia (Thailand) (Fernandes et al. 2007) (Padula et al. 2008) (Clarke and Ham 2008) (Tanner and Volkman 2009) (Kirchhoff et al. 2011b) (Skirtun et al. 2013) (Georgeson et al. 2014).

Common and market names

Scientific Name	*Thunnus maccoyii*
Common Names	Southern bluefin tuna Bluefin tuna
United States	**Southern bluefin tuna** (FDA 2014)
Australia	Southern bluefin tuna, southern tunny
Japan	When sold as sushi or sashimi: *Minami maguro* (southern tuna) *Indo maguro* (Indo-Pacific tuna)
Thailand	*Pla tuna kreep nam-ngern tai*
Hong Kong	*南方藍鰭鮪魚* or *藍鰭金槍魚*

Indonesia	*Tuna sirip biru selatan*
France	*Thon rouge du sud*

Product forms

Although small amounts are sold to the United States, Europe, and southeast Asia, the vast majority of farmed southern bluefin are destined for the Japanese market (Fernandes et al. 2007) (Padula et al. 2008) (Clarke and Ham, 2008) (Tanner and Volkman, 2009) (Kirchhoff et al. 2011b) (Skirtun et al. 2013) (Georgeson et al. 2014). Southern bluefin tuna are supplied to the Japanese market as whole fish (gilled and gutted) in either fresh-chilled or frozen (ultra low, –65°C) (pers. comm., ASBTIA 2015) form (Aiken et al. 2006) (Clarke and Ham 2008). A limited number of tuna are sold as loins, which are usually vacuum-packed and frozen. Approximately 90% of the tuna are frozen, and the rest are sent as fresh product (pers. comm., ASBTIA 2015).

Tuna sold in Japanese restaurants and markets are sold as sushi or sashimi. In the summer, sushi and sashimi consumption is particularly high from July to August during the Bon Festival (FAO 2004). Farmed southern bluefin is exported to Japan in fresh form during these months to realize optimum market value, but frozen product is generally shipped in September (pers. comm., ASBTIA 2015). Specific cuts of bluefin are sold in a variety of forms based on the fat content of the flesh, although seemingly slight imperfections can dramatically affect value. Primary cuts include *akami* (lean), *chu-toro* (medium), and *o-toro* (high fat) (Figure 2).

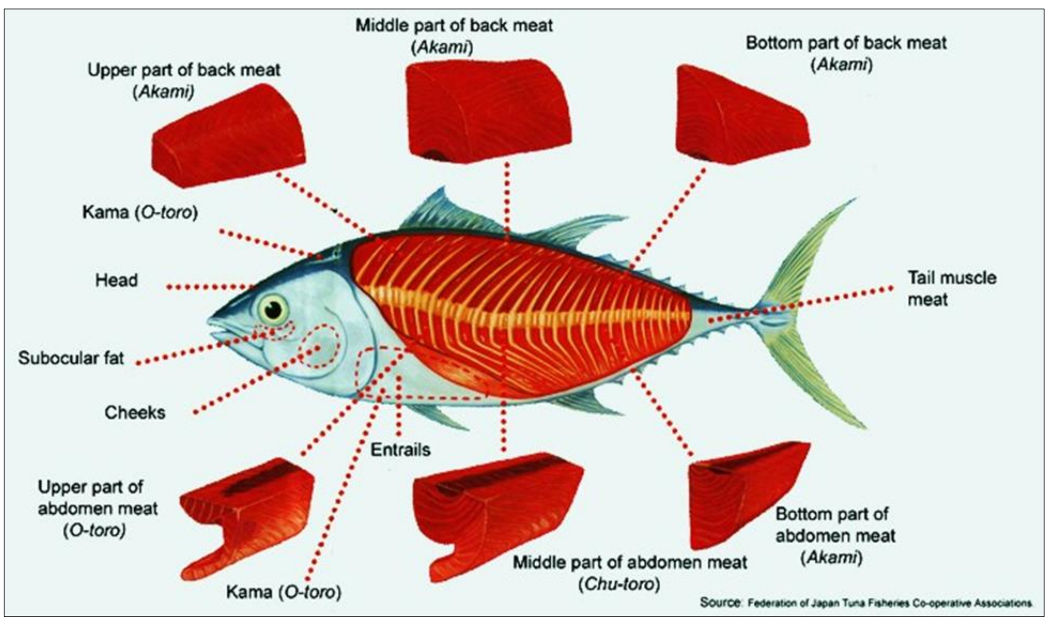

Figure 2. The terms used to describe certain cuts are not specific to bluefin and are applied to all tuna species. Source: Federation of Japan Tuna Fisheries Co-operative Associations.

Industry code of practice

Tuna farmers have developed a code of practice to standardize environmental operations in their industry (Phillips et al. 2009). These operational practices have reduced tuna mortality through improvements in capture and towing techniques, high quality baitfish feed, the virtual elimination of predator mortalities, and an improved understanding of the health impacts of integrating husbandry with environmental management (Nowak et al. 2003) (Nowak et al. 2007). These changes have resulted in the minimization of stress at capture, transport, and holding, as well as a significant reduction in overall mortalities (Díaz López and Bernal Shirai 2007). Industry data have indicated declining farm mortalities since 1997, with the modern Australian tuna industry having a total capture-to-harvest mortality rate of 1%–5% (Nowak et al. 2003) (Nowak et al. 2007) (Clarke and Ham 2008) (pers. comm., ASBTIA 2015).

The industry has been a strong proponent of research and development, and continues to collaborate with both commercial and government R&D programs to increase awareness and knowledge of the biology of southern bluefin tuna and the environment impacts associated with tuna aquaculture (Pecl et al. 2011). Large, commercial-scale baseline datasets have been collected for several decades concerning environmental monitoring, stock performance and health, and the economic viability of farmed southern bluefin maintained in the TFZ (Kirchhoff et al. 2011).

The scope of this assessment is farmed southern bluefin tuna, in Australia, in net pens. Other terms used to describe southern bluefin tuna farming include *ranching*, *penning*, *on-growing*, and *mariculture*.

Analysis

Scoring guide

- Except for the exceptional factors (9x and 10X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.seafoodwatch.org/-/m/sfw/pdf/standard%20revision%20reference/mba_seafoodwatch_aquaculture%20criteria_finaldraft_tomsg.pdf?la=en
- The full data values and scoring calculations are available in Appendix 1

This Seafood Watch assessment involves a number of different criteria covering impacts associated with effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability.[2] As a result of the controversy and polarity of opinions relating to some of these aspects, this report has been reviewed by a number of experts representing a variety of stakeholders.

[2] The full Seafood Watch aquaculture criteria are available at: http://www.seafoodwatch.org/seafood-recommendations/our-standards

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

- *Impact: poor data quality and availability limits the ability to assess and understand the impacts of aquaculture production. It also does not enable informed choices for seafood purchasers, nor enable businesses to be held accountable for their impacts.*
- *Sustainability unit: the ability to make a robust sustainability assessment*
- *Principle: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	5	5
Feed	Yes	5	5
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	5	5
Source of stock	Yes	10	10
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**57.5**

C1 Data Final Score	6.39	YELLOW

Brief Summary

Largely because of the establishment of the Cooperative Research Centre for the Sustainable Aquaculture of Finfish (Aquafin CRC program) between 2001 and 2008, data availability and accessibility regarding the environmental impacts of bluefin tuna farming and related management measures can be considered above average. Aquafin CRC reports include data on waste management, husbandry practices, nutrition and feed development, southern bluefin health, and wildlife interactions. In addition to Aquafin CRC reports, production statistics are published annually by the national Department of Agriculture, and public disclosure processes have been implemented for both aquaculture zone policy development and lease/license assessments under the South Australian Aquaculture Act 2001. Aquafin CRC reports are published online and are accessible to the general public; nonetheless, it is widely accepted that these industry reports are not independent of shareholder influence. Other important data limitations in the literature include reporting exemptions for some chemicals, wildlife mortality rates, disease impacts on wild counterparts, and environmental monitoring data by SARDI. Under these conditions, there is considered to be an overall moderate level of data quality and availability to assess the Australian bluefin tuna farming industry's operations and impacts under Seafood Watch criteria. The Criterion 1 - Data score is 6.39 out of 10.

Justification of Ranking

Key public sources of information or data include:

- Cooperative Research Centre for the Sustainable Aquaculture of Finfish (Aquafin CRC)
    - **Aquafin CRC reports were used as a key source of information throughout this assessment**
    - Cooperative Research Centres (CRCs) are an Australian Federal Government program and are key bodies for Australian scientific research. The CRC for Sustainable Aquaculture of Finfish was established in 2001 and active until 2008. http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/91694/Aquafincrc_annual_report_07_08_final.pdf http://frdc.com.au/research/Documents/Final_reports/2011-525-DLD.pdf
- Primary Industries and Resources South Australia (PIRSA)
    - Aquaculture policy and legislation http://www.pir.sa.gov.au/aquaculture/management_policies
    - Aquaculture leasing and licensing requirements http://www.pir.sa.gov.au/aquaculture/leasing_and_licensing
    - Aquaculture monitoring and environmental assessment http://www.pir.sa.gov.au/aquaculture/monitoring__and__assessment
- South Australian Research and Development Institute (SARDI)
    - Research on aquatic animal health and welfare http://www.sardi.sa.gov.au/aquaculture/aquaculture/aquatic_animal_health__and__welfare
    - Research on nutrition and feed technology http://www.sardi.sa.gov.au/aquaculture/aquaculture/nutrition_and_feed_technology
- Department of Agriculture, Fisheries & Forestry Australia (DAFF)
    - DAFF Biosecurity for aquaculture feed http://www.agriculture.gov.au/biosecurity/import/biological/checklist/animal-feed
- Environment Protection Authority (EPA)
    - Environmental guidelines for completion of PIRSA aquaculture license applications http://www.epa.sa.gov.au/environmental_info/water_quality/aquaculture/epas_involvement_in_aquaculture
- Fisheries Research and Development Corporation (FRDC)
    - Publications on southern bluefin tuna farming research http://frdc.com.au/Pages/home.aspx
- Commission for the Conservation of Southern Bluefin Tuna (CCSBT)

    - Management Procedure http://www.ccsbt.org/site/management_procedure.php
    - Authorized farms http://www.ccsbt.org/site/authorised_farms.php
    - Stock assessment http://www.ccsbt.org/site/recent_assessment.php
- Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)
    - Within the Department of Agriculture, ABARES is a research bureau that publishes annual production statistics on southern bluefin tuna farming http://www.daff.gov.au/ABARES/Pages/Default.aspx
- Australian Southern Bluefin Tuna Industry Association (ASBTIA)
    - An association representing 14 southern bluefin tuna farming companies, which is 100% of the local industry http://www.asbtia.com.au
- International Union for Conservation of Nature (IUCN)
    - Red List - southern bluefin tuna http://www.iucnredlist.org/details/21858/0
- International Seafood Sustainability Foundation
    - Tuna Stock Status Update - 2015 http://iss-foundation.org/resources/downloads/?did=564

In Australia, development of the aquaculture industry is heavily sponsored by government research campaigns. Under the Cooperative Research Centre Program (CRC), a 7-year grant period was established by the Australian Federal Government for research on the Sustainable Aquaculture of Finfish (Aquafin CRC) between 2001 and 2008. Aquafin CRC studies and reports specific to southern bluefin tuna farming are widely accessible and are used extensively throughout this report as a key data source on the environmental impacts of southern bluefin farming, tuna aquaculture husbandry practices, nutrition and feed development, southern bluefin health management, and wildlife interactions. But it is widely accepted that these industry reports are not considered to be independent of shareholder influence. As a result, projects are often highly specified by the industry sector, or information is selectively made available, so that reports are carefully managed and vetted before release (pers. comm., Anonymous 2015) (pers. comm., Anonymous (a) 2015).

For other types of information required in this assessment, data accessibility and availability are variable, depending on the subject matter. Australian bluefin tuna production statistics are available in annually published Australian Fisheries Statistics by ABARES. Although PIRSA and ASBTIA indicate that praziquantel is the only chemical used during the bluefin production cycle, other registered chemicals are nonetheless exempt from reporting requirements under the APVMA Act. Moreover, there are little data on escape statistics because of the native status of southern bluefin to Australian waters, and wildlife mortalities can often go unreported (Tanner 2007). But the source of farm stock for tuna farming is well documented as being fully reliant on the capture of wild tuna for captive stock.

Public disclosure

Public participation is widely implemented in Australia (Phillips et al. 2009). Public consultation is a statutory obligation when considering both aquaculture zone policy development processes and lease/license assessments under the Aquaculture Act 2001. PIRSA has well-established processes for consultation with relevant stakeholders to ensure that environmental considerations are taken into account and addressed for southern bluefin aquaculture development. Members of the public are provided with relevant details of proposed farming activity for all new license applications and are given the opportunity to supply feedback to PIRSA prior to lease and license approval. Furthermore, public access to the results of environmental monitoring program (EMP) reports is available through PIRSA's online Public Register.[3] Access to Tuna Environmental Monitoring Programme (TEMP) reports is restricted to government (PIRSA) and industry (ASBTIA) members, because online TEMP report access is restricted by SARDI.[4] Importantly, although scientific literature based on EMP and TEMP results is widely available through the Fisheries Research and Development Corporation (FRDC) and the South Australian Research and Development Institute (SARDI), there is no public domain reporting of monitoring data in Australia, and analysis that is independent of the government is not possible.

Farm-level data: Handling and research constraints
Experimental work to date with southern bluefin has been particularly challenging. Repetitive handling of bluefin tuna has a substantial impact on its growth performance. Research constraints, including the size and highly active nature of the fish, the requirement that experiments be conducted in offshore net pens, and the high costs associated with such work (e.g., each fish is, on average, worth in excess of ¥ 80,000/USD 500 at market) have restricted technical progress and the capacity for some experiments (Glencross 1999) (Glencross et al. 2002).

Remaining data limitations in assessing the Australian bluefin tuna farming industry include:
- Undisclosed chemical use
- International source fisheries for feedfish
- Wildlife mortality data
- Disease transfer between farm stock and wild counterparts

Data Criterion — Conclusions and Final Score
Overall, data accessibility and availability for Australian southern bluefin tuna farming is above average but variable, depending on the subject matter, and is given a high to moderate score based on current information. The final score for the Data Criterion is 6.39 out of 10.

[3] http://www.pir.sa.gov.au/aquaculture/public_register
[4] http://www.sardi.sa.gov.au/aquatic/publications/marine_environment__and_ecology

Criterion 2: Effluents

Impact, unit of sustainability and principle

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: aquaculture operations minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.*

Evidence-Based Assessment

C2 Effluent Final Score	8.00	GREEN

Brief Summary

The Seafood Watch Effluent Criterion considers impacts of farm waste beyond the immediate farm area or outside a regulatory allowable zone of effect. With a substantial amount of studies available on the effluent impacts of tuna farms, the evidence-based assessment option has been applied to evaluate this criterion.

For southern bluefin tuna farms in Australia, all discharged effluent, consisting of uneaten baitfish and solid/soluble waste, is released untreated from the net pens into the surrounding environment. Monitoring results show that southern bluefin tuna farms typically do not affect the chemical or biological characteristics of the water column. Although benthic deposition can be significant, it is quickly metabolized by the marine environment or exported out of the system by strong hydrodynamic regimes. This reflects high nutrient influx rates but a low, localized accumulation of waste and minimal impacts that are considered temporary. When combined with best management feeding practices, extended fallow periods, and current low stocking densities (2–4 kg m^{-3}), the regional effect of southern bluefin farms is demonstrably unlikely to cause substantial changes to the overall nutrient loading status of Australia's coastal waters. Furthermore, robust and consistent regulatory measures exist throughout the industry to monitor both site-specific and cumulative impacts associated with southern bluefin farming. Overall, the lack of significant local or regional cumulative impacts beyond the immediate vicinity of Australian southern bluefin tuna farms result in a final Criterion 2 - Effluent score of 8 out of 10.

Justification of Ranking

The Seafood Watch criteria assess the environmental impacts from waste discharged by Australian southern bluefin tuna farms in both the Effluent and Habitat Criteria as follows:

- This Effluent Criterion (C2) assesses impacts of both particulate and soluble wastes beyond the immediate farm area or a regulatory allowable zone of effect (AZE).
- The following Habitat Criterion (C3) assesses the impacts of primarily particulate wastes directly under the farm and within a regulatory AZE.

Though the two criteria cover different impact locations, there is inevitably some overlap between them in terms of monitoring data and scientific studies. The majority of this information will be presented in this Effluent Criterion, with the intent of minimizing (but not entirely avoiding) replication in the Habitat Criterion.

Effluent production and dispersal

Organic waste is discharged by southern bluefin tuna farms in the form of uneaten feed, fecal matter, and other excretory waste that are released into the surrounding ocean environment in both dissolved and particulate form (Fernandes et al. 2007). The amount of waste generated by farmed southern bluefin depends on several factors:

1. <u>Feeding regime</u>
   Various feed strategies are employed, depending on the management practices of individual farmers. Tuna are fed once or twice daily, 6 or 7 days a week (Clarke 2002) (Cardia and Lovatelli 2007) (Tanner 2007) (Clarke and Ham 2008) (Thomas 2010).
2. <u>Feed-fish species composition</u>
   Baitfish feed is mostly sourced on a local basis, but a variety of species of mixed origin are also used as feed (Fernandes et al. 2007) (Padula et al. 2008) (Tony's Tuna Int'l 2010).
3. <u>Farming period</u>
   The rearing period (and resulting waste production) employed by individual farmers varies, depending on each company's management and marketing strategy.
4. <u>Water temperature</u>
   Seasonal variability affects metabolism and feed rate (Glencross et al. 2002). The feeding rates employed by farmers were as low as 1% of bodyweight in winter and as high as 15% in the first month of stocking (Fernandes et al. 2007b).
5. <u>Harvest frequency</u>
   A partial harvest reduces waste production between net pens, whereas a complete harvest removes waste production at farm sites entirely.

To reduce the volume of organic waste released into the surrounding environment, there have been proposals to integrate polyculture into southern bluefin tuna farming (Mount et al. 2007). Open-ocean polyculture does not occur in South Australia (SA) because regulations (Aquaculture Act 2001) state that within the TFZ, southern bluefin and other finfish may not be farmed together under the same lease (unless approved for research purposes), with other forms of polyculture requiring individual approval by PIRSA. Other proposed waste remediation strategies include feeding systems (feeding strategy and diet), engineered waste-retention systems (cost-prohibitive in open-ocean environment), and limits on stocking density (not a PIRSA license requirement since 2005) (Mount et al. 2007). Currently, the only environmental management strategies in place to reduce the impact of discharged waste by southern bluefin farms in Australia are fallowing (Fernandes et al. 2007) and mandatory stocking densities at ≤ 6 mt per ha.[5]

Given the endothermic characteristics of southern bluefin and a metabolic rate that is three to four times higher than other active teleosts (Fernandes et al. 2007) (Fitzgibbon et al. 2008), only a small fraction of the nitrogen input from feed is retained for growth, and a large amount of effluent is typically released by farmed tuna (Fernandes et al. 2007). High rates of nitrogen excretion in urine and through the gills account for the low nitrogen retention in tuna for growth (7%–12%), high losses of dissolved waste to the water column (59%–64%), and proportionally lower losses as fecal matter (8%–12%) (Fernandes et al. 2007b). As a result of these biological characteristics, the majority of the nitrogen from feed inputs (76%–86%) is released into the water column in dissolved form (Fernandes et al. 2007). These dissolved nutrients are available for uptake by phytoplankton and macroalgae (i.e., seaweeds) in the vicinity of southern bluefin tuna farms.

In Australia, 14 active southern bluefin tuna farming companies are currently operating within the TFZ in SA (pers. comm., Anonymous (b) 2015). Farmers are issued a lease area large enough to allow the relocation of net pens within the lease area every year, thus allowing each previously farmed area to fallow for a mandatory period of at least 12 months after each harvest (pers. comm., Anonymous (b) 2015). Lease areas ranged from 4 ha to 391 ha (mean 63 ha) and, in 2011, occupied 25.84 km^2 (2,584 ha) of the 172 km^2 available in the TFZ (pers. comm., Anonymous (b) 2015). This physical footprint can safely be considered to be relatively small compared to the total marine coastal area of Australia. Although a maximum capacity of 24,860 MT is allowed under TFZ management guidelines (Aquaculture [Zones—Lower Eyre Peninsula] Policy 2013—PIRSA 2014b), the southern bluefin tuna farming industry only produced 7,544 MT during the 2013–14 season (pers. comm., Anonymous (b) 2015). Overall, the regional effect of southern bluefin farms is unlikely to cause severe changes to the overall nutrient loading status of Australia's coastal waters, although local impacts cannot be discounted.

Complex waste dispersion

It should also be noted that the fate of organic waste at marine net pen finfish farms is complex and undertakes multiple pathways. The environmental impact deriving from the release of organic waste depends upon the farming location and the nature of the receiving water body in

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[5] i.e. https://aquapubreg.pir.sa.gov.au/new/piims/FullDetails/show?licID=AQ00057
https://aquapubreg.pir.sa.gov.au/new/piims/FullDetails/show?licID=FB00079
https://aquapubreg.pir.sa.gov.au/new/piims/FullDetails/show?licID=FB00051

terms of ecological context and site-specific hydrographic characteristics. Nutrients supplied to the fish via feed are digested; metabolic waste is released directly into the water column, and material not digested is excreted as feces. A large percentage of particulate waste released from net pens may be consumed before settling or accumulating on the seafloor. Particulate fecal matter and excess feed from southern bluefin farms provide feeding opportunities for a range of opportunistic demersal and benthopelagic fish; the most common finfish scavenger at southern bluefin farms is Degen's leatherjacket *(T. degeni)* (Hayward et al. 2011). Where only 2%–3% of baitfish feed is left uneaten, the high level of scavenging activity reduces the biodeposition surrounding southern bluefin tuna farms (Fernandes et al. 2007) (Svane and Barnett 2007). As a result, the major source of waste in the sediments from tuna farms was recognized to be feces (73%–89%) in comparison to uneaten feed. In addition to these biological attributes, the hydrodynamic regime (current speed, wave action) and geographic exposure (water depth, distance from shore) of the TFZ influences the transport and dispersion of organic material (Fernandes et al. 2007) (Tanner and Volkman 2009). In the farms' current location outside Boston Bay, waste from southern bluefin farms is subject to stronger currents and fast turnover periods (2–20 day flushing period), in addition to uptake and dispersal by scavengers (Fernandes et al. 2007) (Tanner and Volkman 2009).

Water column impacts

Southern bluefin tuna farms release dissolved and solid waste into the surrounding environment. The ability of the environment to assimilate these by-products depends on the rate of physical dispersal of the waste and biogeochemical transformations of the organic and mineral substances in the sediments and water column.

Initially, when tuna pens were located in shallower, sheltered sites within Boston Bay, the impact to the water column was considered minor despite local disturbances to the marine environment (Fernandes et al. 2007). After the relocation of most farms to the offshore farming zone seaward of Boston Island (as a result of the 1996 storm mortalities), average algal counts and chlorophyll-a levels recorded in the TFZ between 1996 and 1998 were characteristic of an oligotrophic coastal system (Clarke et al. 1999) and only marginally higher in the vicinity of the tuna pens. A subsequent monitoring campaign in the summer of 1999 and 2000 showed lower but acceptable dissolved oxygen levels (88.6% saturation) in the vicinity of the net pens (Clarke et al. 2000). Furthermore, salinity, turbidity, pH, nutrients, and chlorophyll-b did not change significantly with distance from the net pens. More recent work also confirmed that chlorophyll-a concentrations are only slightly higher in the vicinity of net pens (Bierman 2005). Although the tuna industry increases the phytoplankton biomass in the TFZ, model-predicted increases occurred in a relatively small area of the TFZ (20%) and for a relatively short time (< 4 months) (Tanner and Volkman 2009). Overall, long-term monitoring of the TFZ has indicated that nutrient fluxes are not sufficient to affect water column nutrients and phytoplankton levels (Bierman et al. 2005) (Clarke et al. 1999) (Clarke et al. 2000), suggesting that southern bluefin farms do not significantly impact the chemical or biological characteristics of the water column. These results are supported by similar studies at bluefin tuna farms in the Mediterranean (Axiak et al. 2002) (Vezzulli et al. 2008) (Aksu et al. 2010) (Vizzini and Mazzola 2012) (Scott et al. 2012) and Mexico (Zertuche-González et al. 2008).

Benthic impacts

Analysis of benthic nutrient fluxes at active farm sites indicated significant changes through a shift to finer sediments where infaunal abundance is greater and where diversity, number of taxa, and evenness is lower (Putro et al. 2007) (Fernandes et al. 2007). Despite high sedimentation rates (10x), oxygen uptake rates (7x), and elevated ammonia and phosphate levels (1–2 orders of magnitude) in the vicinity of southern bluefin net pens, studies have found that the redox potential in the sediments remained positive, and sedimentary organic carbon and total nitrogen contents adjacent to stocked net pens were not significantly different from control sites (Lauer et al. 2007) (Fernandes et al. 2007). Furthermore, the elevated environmental parameters observed as the farming season progressed were matched by decreases after the season ended (Lauer et al. 2007). Combined with the high solubility and slow settling velocity characteristics of southern bluefin feces, waste contributions by farmed southern bluefin have been shown to produce low levels of biodeposition (Fernandes et al. 2007) (Fernandes et al. 2007b). These results suggest that, although inputs are significant, they are quickly metabolized by the marine environment, reflecting high influx rates but a low, localized accumulation of waste and minimal impacts to the benthos at southern bluefin farm sites. As a result, the effects of southern bluefin farms on benthic metabolism are considered temporary and changes are reversible as a result of fast turnover periods (Fernandes et al. 2007) (Lauer et al. 2007). In addition to these studies on benthic metabolism, an environmental monitoring study from 2001–2003 assessing infaunal abundance and diversity found no localized impact at 150 m outside and down-current from tuna farming lease boundaries during the 3-year study period (Loo 2006).

Since 1997, benthic monitoring has been implemented by SARDI under the Tuna Environmental Monitoring Programme (TEMP), and little evidence of impacts from southern bluefin farms has been found on the benthic environment around lease sites (Lauer et al. 2007). The TEMP monitors the environment surrounding each company's lease sites, based upon compliance points, set up 150 m from the edge of the lease sites' boundaries. The monitoring program samples the sediment and uses macro-infauna analysis to monitor the level of impact of each tuna farming company. From these monitoring results, no company has exceeded the legislated limits since 1996 (Clarke et al. 2000) (Madigan et al. 2003) (Jong and Tanner 2004) (Loo et al. 2004) (Loo and Drabsch 2005) (Fernandes et al. 2007) (Lauer et al. 2007) (Tanner 2007) (PIRSA 2013e).

Overall, results from previous studies (Cheshire et al. 1996) (Bruce 1997) (Cronin et al. 1999) (Clarke et al. 1999) (Clarke et al. 2000) suggest that pelagic impacts are negligible and that benthic impacts are minimal and restricted to the immediate vicinity of tuna net pens. Significant localized impacts have not been detected in several monitoring campaigns undertaken since 1996 (Fernandes et al. 2007). Thus, bluefin tuna farms produce negligible impacts to water quality, and benthic impacts beyond the immediate farm area are considered temporary and reversible rather than chronic, as a result of fast turnover periods. Furthermore, the high proportion of dissolved waste generated by farmed southern bluefin combined with the low settling velocity of their feces and the high scavenging activity in the area contribute to minimal impacts to the local benthos. When combined with efficient feeding practices, extended fallow periods, and current stocking densities (2–4 kg m^{-3}), the regional effect of southern bluefin farms is unlikely to cause severe changes in the overall nutrient loading status of Australia's coastal waters. As a result, mandatory fallowing has been considered successful as the single regulatory management tool used to control the environmental impact of southern bluefin tuna farming (Fernandes et al. 2007) (Mount et al. 2007). Therefore, the potential for cumulative impacts from adjacent sites or from the industry's total impact area is considered low.

Effluent management and regulatory effectiveness in Australia

The aquaculture industry in South Australia is regulated by a number of environmental controls:

- Initial site assessments
- Application of license conditions by PIRSA in conjunction with the Environment Protection Authority
- Application of the Aquaculture Regulations 2005
- Ongoing environmental monitoring and site inspections
- Ongoing cooperative research between government agencies and the tuna farming industry
- Development of zone-specific carrying capacities based on environmental parameters and industry farming practices

In Australia, southern bluefin tuna are farmed exclusively in the state of South Australia. To regulate aquaculture production, South Australia has a single dedicated Aquaculture Act 2001, with subordinate legislation outlining the provisions and regulatory requirements of aquaculture activities (i.e., tuna farming) in Aquaculture Regulations 2005 (NASO 2005) (Phillips et al. 2009).

<u>Aquaculture Act 2001</u>

1. Coordination of environmental agencies, consultation, and referral mechanisms
    - The Fisheries and Aquaculture Division of PIRSA is responsible for administering the Act and Regulations. The Act gives responsibility to a single agency to consistently coordinate interactions with other relevant legislation, government agencies, and environmental monitoring programs (Sloan et al. 2014). PIRSA annually requires southern bluefin tuna farmers to submit an Environmental Monitoring Program (EMP) report as a part of license conditions (even if their licensed site has been inactive).
2. Terms and conditions for aquaculture leases and licenses
    - Both "Tuna Farming Zone Leases" and "Marine Tuna Aquaculture Licenses" are granted by PIRSA. Each new license application undergoes a risk assessment based on Australia's National Ecologically Sustainable Development Framework for Aquaculture (Fletcher et al. 2002) (PIRSA 2013c) (see http://www.aquaesd.com for further references). The assessment framework was developed in conjunction with the National Aquaculture Council (Fletcher et al. 2005) and the Marine and Coastal Committee of the Natural Resources Management Committee, and includes an assessment of approximately 40 possible risk events and applies them to both site-specific and regional levels (Gaylard et

al. 2013). License conditions based on this assessment of approximately 40 possible risk events must be approved by the EPA before an aquaculture license can be granted (pers. comm., Anonymous (b) 2015).

3. Aquaculture Zone policies
   - Aquaculture zones are the primary planning tool for marine aquaculture development in SA. An assessment is conducted to determine which areas are suitable for aquaculture. Once an area is identified, a range of site-specific data are collected, including biological properties and the presence of environmentally sensitive habitats. Proposed Zone policies will then undergo a period of review and consultation with marine stakeholders and the nearby public, before a cabinet review and publication in the Government Notices Gazette. Under the Aquaculture Act 2001, the TFZ and related exclusion zones for southern bluefin farming have been established outside Boston Bay since the late 1990s (Gaylard et al. 2013).

Aquaculture Regulations 2005

For a Marine Tuna Aquaculture license, regulatory requirements associated with effluent management include:

- Ensuring that operational aquaculture waste (not animal) and refuse is treated and not disposed of in the TFZ
- Maintaining a 3-m minimum distance between net pens and the seafloor
- Limiting stocking density (e.g., 6 MT tuna per licensed hectare)

The Environmental Monitoring Program (EMP) requirements for a Marine Tuna Aquaculture license comprise three reporting components, farm management, TEMP, and benthic monitoring and site audit:

Farm management

- Site fallowing plan: Annual report of fallowed areas and the period for which the areas have fallowed. Previously stocked net pen locations must be fallowed for 12 months
- Stocking density: Number of farmed tuna in the license area per month
- Quantity and biomass of captive tuna per month
- Feed and chemical inputs per month
- Any high-mortality event

Tuna Environmental Monitoring Program (TEMP)

- Quantitative comparison of benthic infaunal communities at a company's lease site (identified as a compliance site located 150 m from the lease boundary) and a group of control sites (located at least 1 km from any lease boundary)

Benthic monitoring and site audit

- Annual site visits to assess compliance to license conditions, including video footage of the seafloor under nets.

Regulatory regimes

Environmental monitoring is widely conducted in marine aquaculture in Australia (Phillips et al. 2009). Although PIRSA is responsible for implementing State legislation and aquaculture management in SA, the management of environmental impacts of southern bluefin tuna farming is influenced by a variety of national, state, and nongovernment organizations.

State (SA) environmental agencies

Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture

Aquaculture in South Australia is regulated under the Aquaculture Act 2001, which is administered solely by PIRSA Fisheries and Aquaculture. As a part of developing and implementing aquaculture policies, legislation, and regulatory frameworks, the agency manages a compliance-based monitoring program for southern bluefin tuna farming. Using requirements prescribed in Aquaculture Regulations 2005, PIRSA annually requires tuna farmers to submit an Environmental Monitoring Program (EMP) report (even if their licensed site has been inactive) as a part of PIRSA license conditions. The results of these EMPs are published as a series of TEMP (Tuna Environmental Monitoring Programme) reports by the South Australian Research and Development Institute.

PIRSA has recently completed an independent review of its environmental monitoring program and, over the next 4 years, the following program will be required for the tuna sector:

1. Monitoring the aquatic environment
    - Pelagic (lower trophic) ecosystem, nutrients, and oceanographic monitoring
    - Hydrodynamic and biogeochemical modeling

2. Benthic Infauna—monitoring the sediment
    - Time series analysis of previous DNA data
    - Benthic infauna monitoring
    - Analysis of infauna datasets
3. Individual site audits (annual)
4. Reporting on farming activities (annual)
5. Report on zone performance
6. Regional impacts of nutrient accumulation (proposed research project)

Aquaculture Advisory Committee (AAC)

To manage this program, a steering committee comprised of PIRSA, tuna industry representatives, the South Australian Research and Development Institute, and the Environment Protection Authority will ensure that relevant management occurs. This committee will also be responsible for a review of the program following its fourth year.

Environment Protection Authority (EPA)

The EPA is a mandatory referral agency under the Aquaculture Act 2001 for all aquaculture license applications and amendments, and for lease conversions that occur outside an aquaculture zone. The EPA provides advice on PIRSA policies, legislation, and environmental monitoring programs. When assessing aquaculture applications, the EPA considers the following environmental issues (EPA, 2014):

- **Water quality** - Addition of nutrients into any waters resulting from uneaten feed and feces; use of chemicals and fuels on aquaculture sites.
- **Waste** - Disposal of mortalities and processing waste; cleaning of infrastructure; removal of biofouling.
- **Site contamination** - Settlement of uneaten feed and feces resulting in anoxic sediments; chemical and fuel spills

South Australian Research and Development Institute (SARDI)

SARDI, a research division of PIRSA, is South Australia's principal government research institute. SARDI's Aquaculture and Marine Ecosystems science programs provide scientific and technical advice for government agencies and the aquaculture industry for sustainable development and management of southern bluefin tuna farming in Australia. SARDI aquaculture subprograms relevant to southern bluefin tuna farming include: (1) Aquatic animal health and welfare, and (2) Nutrition and feed technology. SARDI Marine Ecosystems sub-programs relevant to southern bluefin tuna farming include: (1) Environmental Assessment, Mitigation and Rehabilitation, (2) Aquaculture Environment, (3) Marine Pests, and (4) Oceanography.

- SARDI conducts the annual Tuna Environmental Monitoring Program, which monitors the environment surrounding each company's lease sites, based upon compliance points set at 150 m from the edge of the lease boundaries. The monitoring program uses a quantitative comparison of the benthic infaunal communities to monitor the level of impact of each southern bluefin farming company.

FRDC Southern Bluefin Tuna Aquaculture Subprogram

The Southern Bluefin Tuna Aquaculture Subprogram was initiated in 1997 by the FRDC to promote the planning and management of R&D of southern bluefin tuna aquaculture.

Monitoring and reporting requirements

In South Australia, all active tuna aquaculture sites require both a lease and license. A lease grants the exclusive use of an aquatic area for marine aquaculture, while a license then describes authorized activities that can be undertaken at the lease site. In addition to PIRSA license-based monitoring requirements, SARDI is also responsible for an annual Tuna Environmental Monitoring Programme (TEMP).

Licensed-based monitoring
All southern bluefin farmers are required to submit an Environmental Monitoring Program (EMP) report annually for each licensed site as a mandatory condition of their Marine Tuna Aquaculture License (granted under the Aquaculture Act 2001). EMP protocols are outlined in Aquaculture Regulations 2005 and implemented by PIRSA (Tanner 2007) (PIRSA 2013d) (PIRSA 2014).

State monitoring (TEMP) (pres. comm., PIRSA 2015)
In addition to license-based monitoring requirements by PIRSA, SARDI is responsible for annual TEMP reports. The program includes the analysis of infaunal communities through DNA-profiling of 10 indicator taxa. Statistical analysis of the results of the DNA-based assays, and a color score-card system, are then used to measure differences in the infaunal communities between a compliance site located 150 m from an active farm site boundary and a series of control sites located 1 km from any active farm sites. PIRSA and the tuna farming industry determine which sites are to be sampled each year. The same group also holds responsibility for any follow-up action that needs to occur as a consequence of poor EMP results. Results of the SARDI monitoring program have been published as a series of TEMP reports from 1996 to present. To date, no company has exceeded the legislated limits for water column or benthic parameters since the inception of the monitoring program (Jong and Tanner 2004) (Fernandes et al. 2007) (Lauer et al. 2007) (Tanner 2007) (PIRSA 2013e) (pers. comm., ASBTIA 2015).

Carrying capacity models
In Australia, tuna farm carrying capacity is based on water quality guidelines, in which monthly feed rates and the resulting nutrient flux within the TFZ are compared to prescribed maximum nutrient concentrations by the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ). These feed rates are used to determine license conditions at all southern bluefin lease sites (Middleton et al. 2013). Conservative carrying capacity limits are applied within the TFZ to ensure the maintenance of water quality standards (PIRSA 2013e).

To establish tuna production levels (biomass), a zone-based model for dissolved nutrients and a lease-based model for carbon deposition were developed by Tanner (2007), based on feeding rates, feed composition, stocking densities, current flows, and flushing regimes (Aquafin CRC 2008). These models were used by PIRSA to set initial maximum biomass limits for aquaculture zones and by SARDI to develop TEMP standards. In 2013, updated carrying capacity estimates were developed to meet the anticipated expansion of the tuna industry in SA. The most recent model is area-specific and allows PIRSA to estimate the optimal nutrient fluxes and feed rates at any point in the Gulf at the scale of the net pen, lease, or aquaculture zone (Middleton et al. 2013). Maximum biomass for the TFZ is established by these models and published in Aquaculture Zone Policies (PIRSA 2014b). At the farm level, individual stocking densities are prescribed as a part of lease conditions (Individual farm stocking densities can be found at http://www.pir.sa.gov.au/aquaculture/public_register).

Farm site maintenance
EPA legislation requires that all net biofouling must be removed at a land-based, EPA-licensed facility. Similarly, offal must be disposed of at a licensed land-based facility, and bloodwater must either be disposed of on land or 3 nautical miles from shore as a requirement of Section 17 (1) of the Environment Protection (Water Quality) Policy 2003 (pers. comm., PIRSA 2015). Almost all offal is utilized as fertilizer or recycled into value-added products by SAMPI Pty Ltd (www.sampi.com.au) (pers. comm., ASBTIA 2015).

Public access and transparency
While EMP report results are made available through PIRSA's online Public Register (http://www.pir.sa.gov.au/aquaculture/public_register), access to TEMP reports is restricted to government (PIRSA) and industry (ASBTIA) members, because TEMP reports are restricted by SARDI due to industry intellectual property concerns (http://www.pir.sa.gov.au/research/publications/research_report_series/research_report_series_2015). Public access to scientific literature based on EMP and TEMP reports is widely available through the FRDC and SARDI, both of which publish tuna farming research online.

Penalties for infringements
As a part of lease and license conditions, monetary penalties may be assessed for violating regulatory conditions. Maximum penalties of AU 35,000 and AU 10,000 exist for operating without a license and violating mandatory provisions, respectively. Furthermore, any offense violating conditions of the Aquaculture Act 2001 or any other Federal or State aquaculture or environmental regulation can lead to an order to carry out works, cease and desist from particular activities, or license or lease suspension or cancellation.

Regulating cumulative impacts
A potential for regional cumulative impacts exists in cases where sites are located close together or in poorly flushed areas. SA environmental management agencies have addressed the potential for cumulative impacts by establishing designated aquaculture zones with zone-level carrying capacity limits, and imposing a 1-km minimum distance requirement between farm sites to further reduce the risk of cumulative impacts (Fernandes et al. 2007).

Within the TFZ, southern bluefin operations are exposed to a very well-flushed, high-energy, open-water system, where current speeds in excess of 10 cm s^{-1} are not uncommon and peak at values above 25 cm s^{-1} (2–20 day flushing period) (Fernandes et al. 2007) (Tanner and Volkman 2009) (Kirchhoff et al. 2011). Largely because of siting of southern bluefin farms in highly exposed offshore areas, the potential regional effects of tuna farming have been considered very low in past government regulatory environmental monitoring studies (Fernandes et al. 2007). It is important to note that the current benthic monitoring design may not capture the full extent of benthic impacts beyond 150 m in a high energy system. Considering the apparently restricted nature of environmental impacts associated with southern bluefin farming and the regulations in place to limit cumulative impacts, significant ecological impacts on a regional scale are possible but appear unlikely in Australia's tuna farming industry.

Effluent Criterion—Conclusions and Final Score

Southern bluefin tuna farms occupy a relatively small physical area compared to the total extent of Australia's coastal waters. Although there has been a reduction and consolidation of southern bluefin farms primarily because of a significant quota reduction in 2009, PIRSA has indicated that it plans to develop a number of new aquaculture zones around South Australia over the next 5 years.

Southern bluefin farms release substantial amounts of unmitigated waste into the surrounding marine environment (due to a high eFCR), but a number of biological, environmental, and operational factors result in a low potential for significant impacts beyond the immediate farm site. The high proportion of dissolved nutrients released by farmed tuna is mitigated by diffusion and dilution in the water column, and the remaining fraction of highly soluble particulate waste (feces) is either quickly metabolized by the benthic environment or dispersed and transported by strong flushing regimes and fast turnover periods, due to their low settling velocity. Furthermore, uneaten baitfish is typically consumed before accumulating on the seafloor by high rates of scavenging activity in the area. The majority of studies indicate that, when combined with the use of substantial fallow periods between production cycles, low stocking densities, and efficient feeding practices, southern bluefin farms have little impact on water quality, and the overall benthic impacts are minor and generally restricted in space due to the pelagic dispersal and rapid benthic metabolism of waste beyond the immediate vicinity of the farm. Given that accumulation of organic matter in the sediments at tuna farms has not been observed in government monitoring programs since 1996 or in benthic samples obtained for the Aquafin CRC environment programs since 2001, the minor environmental impacts associated with effluent discharges from southern bluefin farms are considered temporary and largely reversible with fallowing.

Regarding waste management, robust and consistent regulatory measures exist throughout the industry to monitor both site-specific and cumulative impacts associated with southern bluefin farming. Research and compliance monitoring currently focus on both the impacts near net pens (particulate waste: uneaten feed, fecal matter) and also consider the cumulative effect of farming operations on a regional scale through monitoring programs and the development of large-scale models to anticipate the environmental implications of expansion into new lease areas. In addition to independent monitoring by the state (TEMP), annual EMP reports are a mandatory license-based requirement under Aquaculture Regulations 2005. Although the results of individual EMP reports by the tuna farmers are widely disseminated by SARDI and the FRDC, there is no public access to technical EMP monitoring data, and access to TEMP reports is confidential.

Overall, the demonstrated lack of local or regional cumulative impacts beyond the immediate vicinity of Australian southern bluefin tuna farms and the robust and effective effluent management scheme result in a Criterion 2 - Effluent score of 8 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

- *Impact: Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats and to the critical "ecosystem services" they provide.*
- *Sustainability unit: The ability to maintain the critical ecosystem services relevant to the habitat type.*
- *Principle: aquaculture operations are located at sites, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats.*

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		9.00	
F3.2a Content of habitat regulations	5.00		
F3.2b Enforcement of habitat regulations	4.50		
F3.2 Regulatory or management effectiveness score		9.00	
C3 Habitat Final Score		**9.00**	**GREEN**
Critical?	NO		

Brief Summary

In southern bluefin tuna farming, the floating net pens have a minimal direct habitat impact, and benthic impacts produced by individual farms are generally limited to an area directly beneath the farm site. Given the relatively confined nature of benthic impacts, the potential for cumulative impacts from adjacent sites or from the industry's total impact area are considered low. For Habitat Conversion and Function (Factor 3.1), the compositional characteristics of tuna waste, the hydrographic setting of the Tuna Farming Zone (TFZ), and the operational factors employed by the tuna farming industry result in low accumulations of organic matter in the sediments beneath tuna net pens and a score of 9 out of 10. The implementation of aquaculture zones in SA includes a site selection process, which ensures the avoidance of critical habitats and a robust review of the ecological appropriateness of the region for southern bluefin farming. Fallowing requirements by the SA government largely lead to recovery and are considered successful at preventing the accumulation of solid waste beneath tuna net pens. Furthermore, public participation and transparency is widely implemented in Australia, with well-established processes to ensure that environmental considerations are addressed during both lease/license and aquaculture zone development. For Habitat and Farm Siting Management (Factor 3.2), the effective habitat regulations and the subsequent absence of significant benthic impacts beneath active tuna farm sites results in a score of 9 out of 10. When combined, these conditions result in an overall Criterion 3 - Habitat score of 9 out of 10, indicating a "low" level of concern for habitat impacts.

Justification of Ranking
Finfish net pens are open systems that act as point sources of waste in coastal areas. The deposition of solid waste and uneaten feed underneath net pens can potentially change the physical structure and nutrient availability in the sediments and can strongly influence the abundance and diversity of benthic communities.

Factor 3.1. Habitat conversion and function
In Australia, generally about 10% of the total area of any aquaculture zone is allocated to leaseholders (PIRSA 2013e). In 2015, the tuna farming industry occupied a combined physical area of 17.7 km^2 (1,770 ha) within the TFZ. Noting that farm operators are issued a lease area large enough to allow individual net pens to be fallowed every 12 months, this physical footprint can safely be considered relatively small compared to the total coastal area of Australia. With production levels around 35% (7,544 MT from 2012–13) of the maximum carrying capacity (24,860 MT) allowed in the TFZ (PIRSA 2013b) (pers. comm., Anonymous (b) 2015), the cumulative effect of southern bluefin farms is unlikely to cause severe changes to the overall nutrient loading status of Australia's coastal waters. Combined with the localized nature of benthic impacts (Fernandes et al. 2007), the reduced number of licensed southern bluefin farm sites in the TFZ, and a mandatory 1-km minimum distance requirement between farm sites (Aquaculture Regulations 2005), the overall potential for cumulative impacts between adjacent sites or from the industry's total impact area is considered low.

It must be noted that southern bluefin tuna in the Indian Ocean migrate in shallow waters along Australia's southern coast during feeding migrations. It is clear that bluefin tuna farms in SA occupy the same area considered to be key feeding grounds for juvenile southern bluefin tuna, but there is no evidence to indicate that the physical structure of the net pens affects the species' ability to feed in Australian waters.

Benthic impacts beneath southern bluefin tuna net pens
As noted in the Effluent Criterion above, particulate matter and uneaten feedfish can lead to enhanced nutrient levels and increase sedimentation rates of organic waste, such that resulting changes in sediment chemistry can alter macrobenthic communities. Although benthic impacts are expected in the immediate vicinity of southern bluefin farms (Fernandes et al. 2007), the compositional characteristics of tuna waste, the hydrographic characteristics of the TFZ, and the operational factors employed by the industry (e.g., extended fallow period, low stocking density, efficient feeding regime) result in low accumulations of organic matter in the sediments beneath tuna net pens (Fernandes et al. 2007b) (Svane and Barnett 2007) (Putro et al. 2007).

The organic loading beneath southern bluefin farms in Spencer Gulf is relatively low in comparison to other farmed finfish species in Australia (e.g., Tasmanian farmed salmon) (Lauer et al. 2007). As a consequence of the high metabolic demands of southern bluefin tuna, particulate matter makes up only a small fraction (8%–12%) of the waste discharged by farmed southern bluefin (Fernandes et al. 2007b). Combined with the low settling velocity of southern bluefin feces and the high scavenging rates on uneaten feedfish, solid waste represents only a minor component of the total discharges from southern bluefin tuna farms (Fernandes et al. 2007) (Fernandes et al. 2007b) (Svane and Barnett 2007). These relatively small quantities of particulate waste are easily transported and dispersed by the strong flushing regimes present in the TFZ, and any uneaten waste that is not exported out of the system is quickly metabolized in the sediments and released back into the water column as inorganic nutrients (Fernandes et al. 2007). Given the high influx rates but low accumulation, the impact of solid waste on the benthic environment is minor in the vicinity of southern bluefin net pens.

Although a study in 1999 showed that nutrient fluxes at southern bluefin farms can increase levels of organic detritus, fauna, and bivalves up to 50 m from the edge of stocked net pens (Clarke et al. 1999), a more recent study (Lauer et al. 2007) indicates that these increases in nutrients were matched by decreases after the growing season had ended. These results suggest that the effects of tuna farming on benthic communities and metabolism are temporary. Furthermore, organic carbon and total nitrogen contents in the sediments adjacent to stocked net pens were not significantly different from control sites at least 1 km away (Lauer et al. 2007), indicating that particulate waste derived from active net pens was not accumulating on the seafloor at these distances.

In addition to these studies, no benthic samples obtained throughout the duration of the Aquafin CRC program (2001–2007) showed a significant accumulation of organic matter in the sediments beneath tuna farms (Svane and Barnett 2007). Furthermore, EMP data has not shown a significant buildup of particulate wastes directly under or adjacent to active farm sites, or indicated irreversible impacts to benthic flora or fauna to date (Jong and Tanner 2004) (PIRSA 2013e). In cases in which benthic disturbances have been observed, the affected sites began to recover within weeks to months, and the only signs of disturbance after 12 months were a higher fraction of fine sediments, with little impact to the taxonomic richness or diversity of infaunal assemblages (Fernandes et al. 2004) (Putro and Svane 2005) (Putro et al. 2007). These results suggest that benthic changes to sediments adjacent to tuna net pens are reversible as a result of fast turnover periods.

Overall, the low proportion of particulate matter in tuna waste, the low settling velocity of tuna feces, high scavenging rates, and the dispersion of remaining waste by strong hydrodynamic regimes in the TFZ result in a low accumulation of nutrients in the immediate area surrounding net pens. Furthermore, observed increases in nutrients during the rearing period were matched by decreases after the season had ended, suggesting that effects of southern bluefin farming on benthic communities and metabolism were temporary. When combined with industry-wide best farming practices, these factors result in a high Habitat Conversion and Functionality score of 9 out of 10.

Factor 3.2. Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Though the Effluent and Habitat Criteria cover different impact locations, there is inevitably some overlap between them in terms of regulatory and management effectiveness. For additional information on environmental management and monitoring requirements, see the Effluent Criterion.

Aquaculture Zone Policies - Tuna Farming Zone
Aquaculture zones are the primary planning tool under the Aquaculture Act 2001 for marine aquaculture site selection in South Australia. The management framework for each zone is defined in an aquaculture zone policy developed by PIRSA. These policies include an EIA of the region and designate zones suitable for marine aquaculture (Phillips, et al. 2009). Prescribed policy criteria include the species that can be farmed, the amount of area available for leasing, the aquaculture methods that can be used, and the biomass that can be farmed in the area.

Within PIRSA, the South Australian Research and Development Institute (SARDI) is responsible for conducting research to determine the spatial scope for proposed aquaculture zones. The process for developing aquaculture zones begins with a combination of desktop analysis and the collection of field data from a wide variety of regions considered suitable for aquaculture development. Following consultation with the aquaculture industry, smaller areas are identified for possible aquaculture zone development. A range of site-specific data is then analyzed to determine the environmental conditions, sustainable carrying capacity, and ecological appropriateness of the region (PIRSA, 2013c):

- Benthic video analysis
- Water and sediment chemistry analysis
- Sediment in-fauna analysis
- Oceanography analysis
- Carrying capacity modeling

Once a zone policy is drafted by PIRSA, it is referred to the Aquaculture Advisory Committee (AAC). A report supporting the policy is also prepared, and then both documents are made available to relevant stakeholders, state/federal environmental agencies, and the local public. Environmental assessments of coastal aquaculture zones in Australia include widespread opportunities for public participation, leading to extensive public input (Phillips et al. 2009) (pers. comm., ASBTIA 2015). Community stakeholder comments are addressed and incorporated in the policy, which is again reviewed by the AAC, before final approval by the Environment, Resources, and Development Committee of the SA Parliament and the Minister for Agriculture, Food and Fisheries.

The current policy for the TFZ and its supporting report can be found on PIRSA's website at:

- http://www.pir.sa.gov.au/aquaculture/policy_and_legislation_for_aquaculture/zone_policies

Ecological Sustainable Development assessment for new license applications
In South Australia, the Aquaculture Act 2001 requires PIRSA to consider an environmental assessment prior to granting an individual aquaculture license (Phillips et al. 2009). As for all species farmed in South Australia, a comprehensive environmental risk assessment is

undertaken prior to granting a license (Fletcher et. al. 2004). Each assessment is considered independently and co-approved by the Environmental Protection Authority (PIRSA 2013e) (PIRSA 2014c).

With input from the Aquaculture Tenure Allocation Board, PIRSA uses risk-based guidelines to assess potential environmental impacts associated with the proposed aquaculture. These guidelines are based on a nationally accredited best practice Ecological Sustainable Development (ESD) framework (Fletcher et al. 2004), underpinned by the Australian and New Zealand Standard for risk management (AS/NZS ISO 31000:2009) (PIRSA 2013b). In conjunction with the National Aquaculture Council and the Marine and Coastal Committee of the Natural Resources Management Committee, the ESD framework is modified to be specific to southern bluefin aquaculture (Tanner 2007) (Jong and Tanner 2004). These assessments consider the potential environmental impacts at both the site and regional/cumulative level (Tanner 2007) (PIRSA, 2013b).

As part of the assessment for all new applications, there is an extensive consultation process with relevant stakeholders to ensure that environmental considerations are addressed during both lease/license and aquaculture zone development stages. In addition to public notices, notification is also sent to relevant industry bodies (e.g., fishery associations and neighboring aquaculture license holders) and South Australian government agencies (PIRSA 2013e) (PIRSA 2014c). Furthermore, changes to the conditions of existing licenses must be referred to the Environment Protection Authority for consideration as well.

Fallowing practices

The only environmental management strategy to reduce the benthic impacts of southern bluefin farming currently in place is fallowing, which involves relocating net pens from their former location once annually to prevent the accumulation of solid waste within a particular area, per regulation 17(e) of the Aquaculture Regulations 2005 (pers. comm., PIRSA 2015). Although a fallow period of 1 year is stipulated as a mandatory requirement in Aquaculture Regulations 2005, 17(e), the current environmental management regime requires operators to fallow farmed sites for 2 years to allow local benthic recovery (Fernandes et al. 2007) (pers. comm., ASBTIA 2015).

According to the literature, an examination of macrobenthic assemblages beneath fallowed sites indicated that sediment recovery during fallowing is slow, with some sites remaining moderately disturbed after 12 months (Putro et al. 2007). But these sites naturally contained finer sediments and higher infauna abundance, with assemblages characterized by low diversity, number of taxa, and evenness. Sediment recovery is considered to be site-dependent, in which the benthic assimilative capacity at individual sites varies according to their location within the TFZ (Fernandes et al. 2007). Because this study has only evaluated the first year of fallowing, the actual period necessary for benthic conditions to return to background levels currently remains unknown.

Despite the slow recovery rates observed at some fallowed sites, fallowing largely leads to recovery and is considered successful as the single regulatory management tool used to control the benthic impact of farmed southern bluefin tuna (Mount et al. 2007). At the majority of fallowed sites, organic detritus is quickly assimilated in the first few months of fallowing, and the only signs of disturbance after a year were a higher fraction of fine sediments, with little impact to the taxonomic richness or diversity of infaunal assemblages (Fernandes et al. 2004) (Putro and Svane, 2005) (Putro et al. 2007). Although a moderate level of disturbance was still noticeable after 12 months of fallowing, the low accumulation on the benthos suggests that the current fallowing regime over 24 months, together with current best farming practices, result in minor impacts to the benthic habitat beneath tuna net pens (Fernandes et al. 2007) (Putro et al. 2007).

Critical habitat protection

In Australia, the protection of critical marine habitat from aquaculture impacts is implemented at the national (commonwealth) and state level:

<u>Commonwealth legislation</u>

Under Australia's Ocean Policy and Native Vegetation Act 1991 and the Environment Protection and Biodiversity Conservation Act 1999, PIRSA applies broad guidelines to exclude aquaculture over seagrass, reef, and macroalgae considered significant to local ecology (NASO 2005) (Gaylard et al. 2013) (PIRSA 2013b). Though the Native Vegetation Act 1991 specifically provides for the protection and restoration of native Australian vegetation, the Environment Protection and Biodiversity Conservation Act 1999 also mandates habitat recovery and threat-abatement planning if restoration or rehabilitation is needed to avoid a significant adverse impact on a threatened species or ecological community (NVA 2014) (EPBCA 2014). Furthermore, aquaculture activities are also excluded in buffer zones around areas of conservation, including seal colonies and aquatic reserves (PIRSA 2014c).

<u>State legislation</u>

In accordance with provisions set in the Aquaculture Act 2001, aquaculture management by the EPA and PIRSA must be consistent with any relevant environmental protection policy under the Environment Protection Act 1993, which mandates ecologically sustainable development. Furthermore, a minimum 1-km wide aquaculture exclusion zone is established within the mean high watermark on the mainland and around conservation parks (PIRSA 2013e).

A comparison of the benthic habitats surrounding Boston Bay (Figure 1, following page) with recent farm siting records by PIRSA (Figure 2) indicates that the TFZ is situated over bare sand and not on seagrass meadows (*Posidonia* spp) or within marine park boundaries.

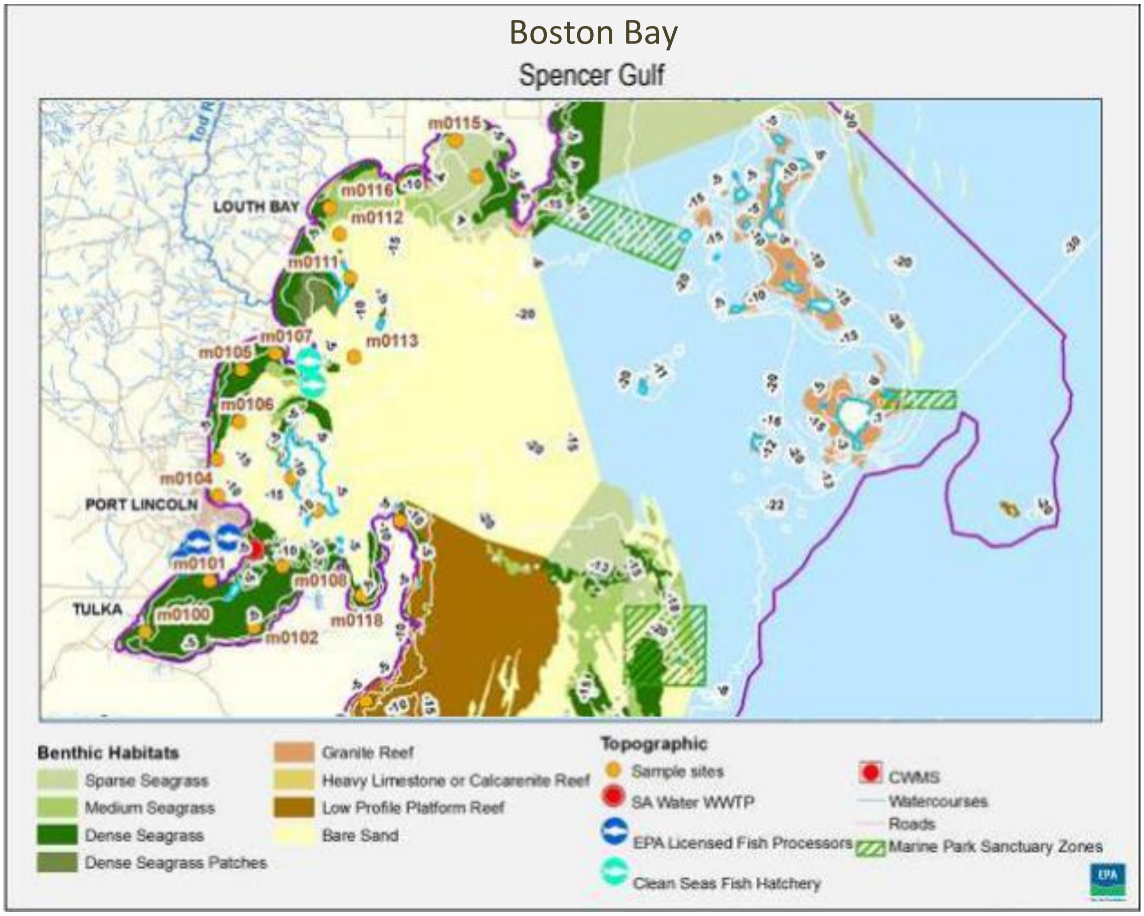

Figure 1: Benthic habitats around Boston Bay (Adapted from Gaylard et al. 2010)

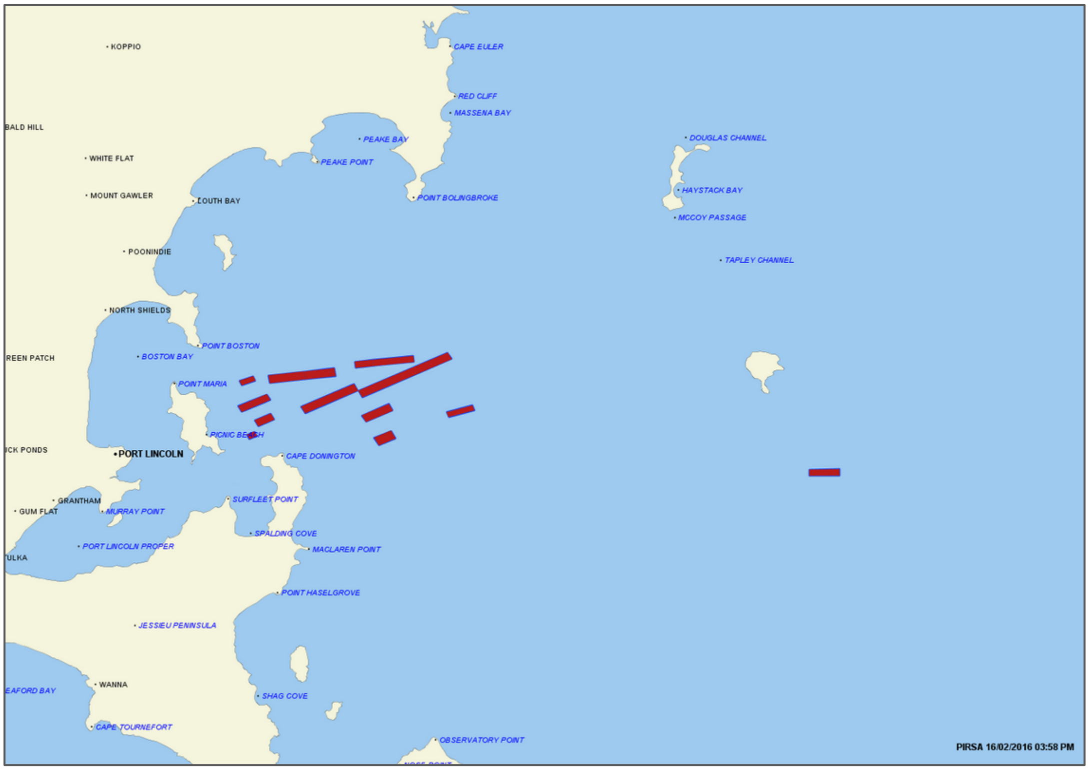

Figure 2: Active tuna farming sites (Source: https://aquapubreg.pir.sa.gov.au/page/gui3/map.html).

Regulatory effectiveness and enforcement

Under the Aquaculture Act 2001, PIRSA is the primary state aquaculture management agency for all interactions between the state government and the aquaculture industry (PIRSA 2014c). PIRSA is responsible for coordinating interactions with other relevant legislation and government agencies, conducting referrals to various government agencies when developing zone policies or considering license applications, coordinating environmental monitoring programs, and creating formal consultation mechanisms (Sloan et al. 2014).

To ensure compliance with lease/license conditions and monitoring requirements, PIRSA Fisheries and Aquaculture Environmental Assessment Officers are involved in the planning and execution of site audits together with Compliance Officers. The site audits cover each major sector on a biannual basis. Issues such as impacts to benthic habitats and waste discharges are actively investigated (PIRSA 2014c). PIRSA performs targeted, sector-wide inspections, which include checking waste security and farm management practices. Follow-up by PIRSA provides feedback to license holders regarding compliance or noncompliance. Furthermore, to bring particular environmental infractions to PIRSA's attention, the public can report to PIRSA directly through FISHWATCH (http://www.pir.sa.gov.au/aquaculture/fishwatch). Since 1996, there has yet to be a tuna farming company that has exceeded legislated EMP limits (Jong and Tanner 2004) (Lauer et al. 2007) (Fernandes et al. 2007) (Tanner 2007) (PIRSA 2013e).

Public participation is widely implemented in Australia (Phillips et al. 2009). PIRSA has well-established processes for consultation with relevant stakeholders to ensure that environmental considerations are addressed during both lease/license and aquaculture zone developments. Members of the public are provided with relevant details of proposed farming activity for all new license applications and are given the opportunity to submit feedback prior to lease and license approval. Although public access to EMP report results is made available through PIRSA's online Public Register,[6] access to TEMP reports is restricted to government (PIRSA) and industry (ASBTIA) research (online TEMP access is restricted by SARDI[7]). Although public access to scientific literature based on EMP and TEMP reports is widely available through the FRDC and SARDI, public compliance verification from these reports is not possible without data disclosures in the public domain. As a result, transparency in the enforcement process is only considered in this report to be moderately achieved.

Overall, the implementation of aquaculture zones in SA includes a site selection process that ensures the avoidance of critical habitats and a robust review of the ecological appropriateness of the region for southern bluefin farming. A comprehensive EIA assessing potential environmental impacts at site-specific and regional levels is performed prior to the issuance of each tuna farming license. Although fallowing currently represents the only environmental management strategy used to reduce benthic impacts in southern bluefin farming, it largely leads to recovery and is considered successful at preventing the accumulation of solid waste beneath tuna net pens. Furthermore, appointing PIRSA as the single government point of contact for the tuna farming industry has resulted in effective environmental regulatory management and coordinated development of southern bluefin farms in SA. Public consultation is compulsory for approval of tuna farming licenses and zone policy development under the Aquaculture Act 2001. Although public access to the results of PIRSA EMP monitoring reports is readily available by public register, there remains limited transparency in the enforcement process without putting SARDI TEMP reports in the public domain. Based on Seafood Watch criteria, Australian southern bluefin tuna farming scores 5 out of 5 for regulatory effectiveness and 4.5 out of 5 for enforcement, resulting in a final management score of 9 out of 10.

Habitat Criterion—Conclusions and Final Score

The final score for the Habitat Criterion is a combination of the habitat conversion score (Factor 3.1) and the effectiveness of the regulatory system in managing potential cumulative impacts (Factor 3.2).

Although benthic impacts are expected in the immediate vicinity of southern bluefin farms, the low proportion of particulate matter in bluefin waste, the low settling velocity of bluefin feces, the high scavenging rates, and the dispersion of remaining waste by strong hydrodynamic regimes in the TFZ result in a low accumulation of organic matter in the sediments beneath tuna net pens. Combined with the localized nature of benthic impacts, a mandatory 1-km distance limit between farm sites, and the reduced number of licensed southern bluefin farms in the TFZ, the overall potential for cumulative impacts between adjacent sites or from the industry's total impact area is considered low. Rigorous license-based monitoring requirements

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[6] http://www.pir.sa.gov.au/aquaculture/aquaculture_public_register

[7] http://www.sardi.sa.gov.au/aquatic/publications/marine_environment__and_ecology

and extensive fallowing practices have resulted in the absence of benthic impacts beyond legislated limits since 1996. Furthermore, strong aquaculture zone polices and the consistent application of national critical habitat protection regulations by SA have contributed to high levels of farm siting effectiveness in Australia. Although public access to SARDI TEMP reports is restricted, public participation and transparency is widely implemented for southern bluefin tuna aquaculture management in Australia. Overall, these conditions result in a high Criterion 3 - Habitat score of 9 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- *Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments*
- *Principle: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use*

Chemical Use parameters	Score	
C4 Chemical Use Score	**6.00**	
C4 Chemical Use Final Score	**6.00**	**YELLOW**
Critical?	NO	

Brief Summary

Currently, praziquantel (an anti-parasitic blood fluke treatment) represents the only documented chemical therapeutant used in southern bluefin tuna farming. Although all therapeutic, prophylactic, or antifouling substances used in the course of aquaculture must be approved by the Australian Pesticides and Veterinary Medicines Authority in Australia, the SA government permits reporting exemptions for some chemicals under human and animal health considerations under the APVMA Act. Overall, southern bluefin is a culture species that has had a demonstrably low need for chemical inputs, but specific data are currently limited. These conditions result in a moderate level of concern under Seafood Watch criteria and a Criterion 4 - Chemical Use score of 6 out of 10.

Justification of Ranking

Historically, a lack of disease and mortality has resulted in a low need for the use of therapeutic agents in the Australian tuna farming industry (Nowak et al. 2003) (Díaz López and Bernal Shirai 2007). There are also practical limitations of their use because of the size of the net pens and the susceptibility of tuna to handling stress (Ottolenghi 2004). But an increase in the intensity of blood fluke infections has resulted in the trial use of praziquantel (anthelmintic) for the parasite *Cardicola forsteri* since 2011 (Hardy Smith et al. 2012) (PIRSA 2012) (Roberts et al. 2014). Injected into baitfish feed over 3-day treatment periods, praziquantel is the only veterinary medicine employed in southern bluefin farming to date (pers. comm., ASBTIA 2015). Importantly, praziquantel is the preferred drug to treat schistosomiasis in humans (Hardy Smith et al. 2012) and trials carried out by PIRSA have established that praziquantel appears to be harmless to the marine environment (FRDC 2014).

Any therapeutic, prophylactic, and/or antifouling substance used in aquaculture must be approved for use as a registered veterinary chemical by the Australian Pesticides and Veterinary Medicines Authority (APVMA) (PIRSA 2013f). Although PIRSA annually requires tuna farmers to submit farm management data documenting monthly chemical inputs under the APVMA Act, some chemicals are exempt from this reporting requirement. These exemptions are designed primarily to protect human and animal health and do not strongly consider chemical impacts to the marine environment (pers. comm., Anonymous 2015). Without robust documentation that accurately identifies all chemical inputs, there is uncertainty regarding chemical use in the Australian bluefin tuna farming industry. Although bluefin tuna is a culture species that has a demonstrably low need for disease-related chemical treatments, the presence of exempt reporting allowances indicate that some chemical use still currently remains unknown.

Praziquantel is not currently registered with the APVMA for use in farmed tuna, but Aquaculture Regulations 2005 (Regulation 10) provides for the experimental use of off-label/unregistered veterinary medicines in aquaculture in consultation with the EPA to maintain fish health and welfare, and to ensure data collection for permit application with the APVMA (pers. comm., Anonymous 2015b). Ministerial approval under Regulation 10 has currently been granted for trial use of praziquantel in commercial southern bluefin farms (PIRSA 2012) (FRDC 2014) (Roberts et al. 2014) (pers. comm., PIRSA 2015).

Chemical Criterion—Conclusions and Final Score

Until recently, veterinary chemical use in southern bluefin tuna farming has been absent due to a lack of disease and mortality in harvestable fish. But increases in blood fluke infections have required therapeutic use of praziquantel since 2011. This anthelmintic drug is regulated by the Veterinary Chemicals Code Act 1994 and Aquaculture Regulations 2005, and must be approved by the APVMA before use in farming operations. Furthermore, licensed-based, self-reporting requirements are used to monitor chemical inputs on a monthly basis. Although an open production system lends itself to the introduction and accumulation of chemicals into the surrounding environment, the apparent lack of pesticide and antibiotic use, current industry fallowing practices, and the hydrographic nature of exposed farm sites significantly reduces the potential for chemical impacts to the environment. Nonetheless, for chemical use in the Australian southern bluefin tuna farming industry, there remains some level of uncertainty regarding the use of chemicals due to a lack of public disclosure by the APVMA. Although specific data may be limited, southern bluefin tuna farms have a demonstrably low need for chemical inputs, and these conditions result in a moderate level of concern and a score of 6 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

- *Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.*
- *Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.*
- *Principle: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	12.50	0.00	
F5.1b Source fishery sustainability score		-4.00	
F5.1: Wild Fish Use		0.00	
F5.2a Protein IN	226.63		
F5.2b Protein OUT	18.17		
F5.2: Net Protein Gain or Loss (%)	-91.98	0	
F5.3: Feed Footprint (hectares)	90.70	0	
C5 Feed Final Score		**0.00**	**CRITICAL**
Critical?	YES		

Brief Summary

Although formulated pellet feeds for other finfish are available in Australia, southern bluefin tuna farms rely solely on the use of whole wild baitfish for feed due to lower feeding costs, higher palatability, and better maintenance of health and welfare. Unlike almost all other aquaculture industries that are focused on growing their farmed stocks, the primary goal of Australian tuna operations is to increase the tuna's fat content for market desirability. Therefore the feed conversion ratio is typically high. Reported economic feed conversion ratios (eFCR) vary from 10–15 for farming juveniles. The exclusive use of whole feedfish means that the Fish In to Fish Out ratio (FIFO) is the same as the eFCR and produces critically high FI:FO ratios (a simple measure of wild fish use) and a score of 0 out of 10. In the wild, tuna also consume baitfish, but do so as part of a complex natural foodweb and ecosystem. The extraction of these two ecosystem components (i.e., the tuna and the baitfish) and their use as inputs in an artificial farming system does not enable them to provide the same ecosystem services that they would in the wild. Local Australian sardine, local redbait, and California sardine represent the most common feed ingredients, but a variety of other baitfish species are utilized as feed. A precautionary Source Fishery Sustainability score of –4 out of –10 was applied to Factor 5.1 (Wild Fish Use), producing a final adjusted score that remained 0 out of 10. Furthermore, a net protein loss greater than 90% and the presence of a significant feed footprint (90.70 ha per ton of farmed fish) represent additional environmental concerns. Overall, the absence of by-products or non-edible processing ingredients as alternative sources of feed protein and the highly inefficient conversion of feed into harvestable fish result in a critical Criterion 5 - Feed score of 0 out of 10.

Justification of Ranking

In Australia, whole wild baitfish are used as the sole feed source for farmed southern bluefin tuna (pers. comm., ASBTIA 2015) (pers. comm., PIRSA 2015). Farmed tuna are purposefully fed a diet of fish with high lipid content to increase their fat stores, making them more desirable to the Japanese sushi and sashimi markets. Feeding practices have been developed to simultaneously accommodate the tuna's large appetite and to minimize the labor required. About 60% of the baitfish feed is usually delivered fresh to the tuna, and the rest is dispensed as frozen blocks suspended underwater in the center of the pens in separate feeder cages (Nowak et al. 2003) (Ottolenghi 2004) (Fernandes et al. 2007) (pers. comm., ASBTIA 2015).

Pelleted Feeds

Although wild-caught baitfish currently represent the primary feed source, the development of a commercially formulated feed was identified as a high priority early in the industry's history as a means to minimize reliance on imported baitfish, reduce FCR, and increase farm production (Barneveld et al. 1997) (Barneveld et al. 2003). From 2001–2008, Aquafin CRC and the FRDC performed a series of research projects in close collaboration with the tuna farming industry to create feed pellets suitable for farmed southern bluefin, but had limited success (Cardia and Lovatelli 2007) (Buchanan and Barneveld 2005) (Buchanan et al. 2000) (Glencross et al. 2002). Strong impediments preventing the creation of a successful product include the extreme costs associated with replicating studies on large valuable fish under commercial conditions, problems encountered in weaning juvenile tuna onto dry artificial diets or moist sausages, absorption of moisture through feeds, and most importantly, because current industry economics reinforce the use of baitfish rather than formulated pellets as feed (Aquafin CRC 2008) (Mourente and Tocher 2009) (pers. comm., ASBTIA 2015) (pers. comm., ASBTIA 2015) (pers. comm., PIRSA 2015).

Since the early 2000s, the ready availability and price of sardines from South Australian waters has removed much of the commercial incentive to develop pelleted feeds (Fernandes et al. 2007) (Tanner 2007) (Aquafin CRC 2008). Enriched diets in pellet form have been developed and tested commercially, but at present, they are not economically competitive in price with locally caught fresh baitfish (no freezing cost), and the development of a commercial pellet to replace baitfish is still in progress (Tanner 2007) (Aquafin CRC 2008) (Leef et al. 2012) (pers. comm., ASBTIA 2015).

In addition to financial incentives, wild feedfish are favored due to a cultural preference in Japan for tuna fattened on non-pelleted feeds. Japanese consumers primarily eat tuna meat raw, so flesh quality (i.e., texture and taste) is very important and varies, depending on the feed policy used by tuna farm operators. Tuna farmers who were hesitant to evaluate recommended manufactured feeds in their commercial farms cited Japanese market resistance to fish reared on pelleted feeds as an impediment (Ottolenghi 2004) (Mourente and Toche 2009). Furthermore, growth performance of southern bluefin that were fed a pellet diet was comparable to that of fish fed baitfish (Smart 1995) (Smart 1996) (Smart 1998) (Glencross et al. 2002) (Ottolenghi 2004) (Fernandes et al. 2007) (Mourente and Tocher 2009). Combined with difficulty in producing a moist pellet feed that is readily taken by southern bluefin (Mourente and Tocher 2009), Australian farmers are reluctant to switch to pelleted feed, so they continue to use readily available baitfish fisheries.

Feeding practices

Southern bluefin farm operators have independently implemented a formalized Industry Code of Practice with regard to feed policy (Nowak et al. 2003) (Nowak et al. 2007) (Fernandes et al. 2007). Farmed tuna are fed once or twice daily, 6 or 7 days a week, depending on season (Clarke 2002) (Ottolenghi 2004) (Tanner 2007) (Cardia and Lovatelli 2007) (Clarke and Ham 2008) (Thomas 2010). The feeding rates employed by the farmers are as low as 1% of body weight in winter and as high as 15% in the first month of stocking (Fernandes et al. 2007b). Approximately 80% of the baitifish feed is delivered as a fresh-chilled product, with the rest block-frozen onshore and stored in freezers before distribution to southern bluefin farms (Musgrove et al. 2011) (pers. comm., ASBTIA 2015). Although the fraction of uneaten feed had varied between 4 and 23% in the first 6 years of the industry (Bruce 1997), more recent video footage beneath net pens suggests much lower values for the modern tuna farming industry in Australia (Fernandes et al. 2007).

Feedfish composition

In the beginning of the tuna farming industry in South Australia, imported baitfish represented a large proportion of the feedfish composition: the amount of foreign baitfish imports gradually increased from approximately 13,000 MT in 1995 (50% of total feed inputs) to approximately 45,000 MT in 2001 (Tanner 2007). Nonetheless, an increase in the TAC for the local sardine fishery since 2000 (Ward et al. 2004) has strongly reduced the demand for imported baitfish feed (Ottolenghi 2004) (Fernandes et al. 2007) (Tanner 2007). Frozen baitfish is still being imported from South Korea and the United States (pers. comm., PIRSA 2015), but it currently represents a smaller feed component (20%–25%), and the majority of baitfish is sourced locally for southern bluefin farming in Australia (pers. comm., ASBTIA 2015).

Approximately 75% of baitfish feed in southern bluefin tuna farming is made of local Pacific sardines *(Sardinops sagax)* (Nowak et al. 2003) (Fernandes et al. 2007) (Tanner 2007) (Padula et al. 2008) (Clarke and Ham 2008) (Tanner and Volkman 2009) (pers. comm., PIRSA 2015), and the bulk (> 95%) of the Australian Pacific sardine TAC quota is sold to feed farmed southern bluefin (pers. comm., ASBTIA 2015). Other important species include Australian redbait *(Emmelichthys nitidus)* and California sardine *(Sardinops sagax caeruleus)*. A minor amount of mixed-origin baitfish species such as mackerel (*Scomber* spp.), herring (*Clupea* spp.), squid (*Illex* spp.), and anchovies (*Engraulis* spp.) are also fed to farmed southern bluefin (Ottolenghi 2004) (Cardia and Lovatelli 2007) (Padula et al. 2008) (Tanner and Volkman 2009) (pers. comm., ASBTIA 2015). But the specific composition of feedfish is not known in most cases due to the commercial nature of the tuna farming industry, in which each company uses its own baitfish composition based on the feed performance achieved over the farm's tenure. Thus, information on feed composition is considered proprietary and is generally not available to the public.

Because the baitfish feed composition is primarily based on maximizing the fat content in farmed bluefin tuna (Thomas 2010), it should be noted that the feeding practices employed by tuna farmers do not reflect the normal food spectrum available to wild bluefin. In the wild, southern bluefin tuna is an opportunistic feeder that feeds on cephalopods (squid and octopi), crustaceans, and a range of different baitfish (Barneveld et al. 1997) (Padula et al. 2008) (Pecl et al. 2011). Because prey items are opportunistically consumed during feeding migrations (Barneveld et al. 2003) (Ottolenghi 2004) (Leef et al. 2012), the prey composition for wild bluefin is more varied than the feedfish provided by Australian tuna farming operations (although according to Fitzgibbon et al. [2008], juvenile tuna do follow sardines during feeding migrations along the Australian Bight).

Ecological impact of wild feed

Although the baitfish species used by tuna farmers represent a normal dietary component of wild southern bluefin, the use of globally sourced wild baitfish for farming is inherently extractive in nature. The sourcing of wild baitfish for farming both increases pressure on local pelagic feedfish resources and creates additional impact on predators that exploit these baitfish as prey. Removal of both the tuna and baitfish from the wild and concentrating them into tuna farms results in the loss of ecosystem services provided by both species throughout their native ranges.

Feed efficiency - Economic feed conversion ratio

An economic feed conversion ratio (eFCR) is used to measure the efficiency of farmed tuna at converting feed into harvestable fish. In the Feed Criterion, an eFCR is used to determine the industry's reliance on wild feedfish, the net protein gain/loss in tuna production, and the ocean-area appropriated for feed ingredients.

Reflecting bluefin's distinctly higher metabolic rates (Korsmeyer and Dewar 2001), feed conversion ratios for farmed southern bluefin are much larger compared to those of other cultured species (Volpe 2005) (Cardia and Lovatelli 2007), and more than double the values for aquaculture species reared on manufactured feeds (Fernandes et al. 2007). The FCR in farmed southern bluefin (and all other fish species) is primarily influenced by water temperature (Glencross et al. 2002) (Fernandes et al. 2007) (Aquafin CRC 2008) (Mourente and Tocher 2009), but also varies because of differences in farming period, feedfish composition, and each farm's individual feeding regimes. Over a farming season, feed conversion ratios typically range from 10–15:1 using baitfish (Ottolenghi 2004) (Ottolenghi et al. 2004) (Cardia and Lovatelli 2007) (Fernandes et al. 2007) (pers. comm., ASBTIA 2015) (pers. comm., PIRSA 2015). Overall, an FCR of 12.5:1 is considered representative of the industry in this Seafood Watch assessment.

Factor 5.1. Wild Fish Use

This factor combines an estimate of the amount of wild fish used to produce farmed southern bluefin with the sustainability of the fisheries from which they are sourced.

Using Seafood Watch Criteria, the use of whole wild baitfish as the only feed input results in a FI:FO value equal to the eFCR for farmed tuna. A FI:FO value of 12.5 indicates that 12.5 tons of wild fish are required to supply sufficient feed for 1 ton of farmed tuna production. The substantial amount of feed input required to produce harvestable farmed tuna results in a FI:FO score of 0.

Source fishery sustainability

Under the Department of Agriculture, Fishery Status Reports are published annually by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and provide the biological status of commercial fish stocks managed by the Australian government. In 2012, the Fisheries Research and Development Corporation (FRDC) also commissioned the development of the first national Status of Key Australian Fish Stocks reports.

For the Australian Pacific sardine *(Sardinops sagax)* fishery, Fishery Status Reports (2013–14) indicate that historical sardine catches have been low in comparison to the estimated overall biomass, and that recent catches have been below the Recommended Biological Catch (RBC). Based on the catch history as a proportion of spawning biomass, the Pacific sardine stocks in Australia are currently classified by ABARES as neither overfished nor subject to overfishing (Georgeson et al. 2014). Furthermore, sardine exploitation rates (catch/spawning biomass) reported by the FRDC indicate that Australian stocks are being fished at sustainable levels that are well below maximum sustainable yield (Flood et al. 2012).

For the Australian redbait *(Emmelichthys nitidus)* fishery, stocks are separately managed and assessed in eastern and western sub-areas. For eastern and western stocks, recent catches are reported to be below RBC or at a low level, respectively (Georgeson et al. 2014). Although the current stock status of the western redbait sub-area is unknown, ABARES does not classify the eastern stock as overfished, and both stocks are not considered subject to overfishing (Georgeson et al. 2014).

North American fisheries for California sardine *(Sardinops sagax caeruleus)* are considered a "Best Choice" by Seafood Watch (Seafood Watch 2013), a "Species of Least Concern" by the IUCN (IUCN,2010), "Not Overfished or Subject to Overfishing" (4/4 points) by NOAA's Fish Stock Sustainability Index (NOAA 2014), "Green" by the Safina Center (Safina Center 2013), and a species of "Little or No Concern" by Oceanwise (Oceanwise 2013).

In addition to the three primary species listed above, baitfish of mixed origin are fed to farmed southern bluefin (Ottolenghi 2004) (Cardia and Lovatelli 2007) (Padula et al. 2008) (Tanner and Volkman 2009), including baitfish imported from South Korea and the United States (pers. comm., PIRSA 2015). Given the variety of baitfish species used and the global sourcing for this feed component, the sustainability of every baitfish fishery contributing to tuna feed in

Australia cannot be assessed with any confidence, because the list of species is indeterminate and in constant change. In Seafood Watch criteria, these conditions result in a precautionary score of –4 out of –10 for source fishery sustainability.

Wild Fish Use Score
A sustainability penalty of –4 is applied to the FI:FO score and generates a final Wild Fish Use score of 0 out of 10, indicating critical conservation concerns.

Factor 5.2. Net Protein Gain or Loss
Aquaculture has the potential to be a net producer of protein, but when external feed is used in any significant quantity, there is typically a net loss of protein when feed is converted into farmed fish. A net protein value is quantified using an average protein content of feed, eFCR, the protein content of whole harvested tuna, and the edible yield of each fish.

In addition to the eFCR, other values used to calculate the net protein consumption in southern bluefin tuna farming:

1. Protein content of feed ingredients
   The specific combination of baitfish used to feed farmed bluefin varies, depending on the availability and cost of shipment. Therefore, the three most commonly used baitfish species (sardine, mackerel, and herring) observed in the literature were used to calculate an average protein content of feed. An average protein content of 18.13% is applied to baitfish feed based on yield values produced by the Southern Bluefin Tuna Aquaculture Sub-Program (Barneveld et al. 2003). All of these species are considered to be "edible" protein sources.

2. Protein content of harvested tuna
   An average protein content of 23% is applied to whole harvested farmed tuna based on research by Aquafin CRC (Fernandes et al. 2007b).

3. Edible yield of harvested tuna
   Based on values compile by FAO, an edible yield of 58% is applied to farmed southern bluefin tuna (Torry Research Station 1989).

For farmed tuna, the overall reliance on external feedfish inputs results in a calculated 92% loss in edible protein, and a critical factor score of 0 out of 10 (due to the > 80% net protein loss).

Factor 5.3. Feed Footprint
This factor is an approximate measure of the global resources used to produce feed based on the area used to produce the ingredients.

The resources used to obtain feedfish for tuna farming are substantial, and a large amount of ocean area is required to produce the feed necessary to grow each farmed fish (90.70 ha ton^{-1}

of farmed fish). The feed footprint for farmed bluefin tuna is considered very high and results in a factor score of 0.

Feed Criterion—Conclusions and Final Score

The final Feed score combines the three factors with a double weighting on the FI:FO score. A high FI:FO value of 12.5 indicates that southern bluefin farming does not increase food production. On average, 12.5 tons of wild fish are used to produce 1 ton of farmed bluefin tuna in Australia. The consequence of this process is a net protein deficit, where > 80% of protein inputs are lost to the environment. The inefficiency of southern bluefin tuna feed is compounded by the significant ocean area appropriated for feed ingredients, because the industry relies almost completely on using wild baitfish for feed. Overall, even though bluefin farming in theory mimics the natural predator-prey relationship in the wild, the highly extractive nature of bluefin tuna farming results in a final Feed Criterion score that is Critical/Red and is scored 0.25 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, predation, habitat damage , spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations*
- *Sustainability unit: affected ecosystems and/or associated wild populations.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Escape parameters	Value	Score	
F6.1 Escape Risk		2.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		10	
C6 Escape Final Score		**10.00**	**GREEN**
Critical?	NO		

Brief Summary

For net pen aquaculture, there is an inherent risk of escape from catastrophic losses or more chronic “leakage.” But given that farmed tuna are the product of capture-based aquaculture and that captive tuna originate from Australian waters, the risk of ecological (i.e., competitive and/or genetic) impacts of escaped tuna on other wild species or wild counterparts is considered to be minimal. The resulting Criterion 6 - Escape score is therefore 10 out of 10.

Justification of Ranking

The Escape Criterion combines the risk of escape with the potential for ecological impact of the escapees. The capture-based nature of bluefin farming in Australia creates unusual escape dynamics, and inevitably a lower level of concern regarding potential ecological impacts of escapes, as discussed below.

Factor 6.1a. Escape risk

Fish escapes from fish farming sites is an inevitable occurrence resulting from human error during routine handling, mechanical failures, damage caused by adverse weather conditions, or aquatic predators such as seals and dolphins tearing the nets (Grigorakis and Rigos 2011).

In southern bluefin tuna farming, operational “leakage” losses are associated with tuna escapes during initial capture, fish transfer between purse seines and transport cages, and net-herding maneuvers at harvest. Large-scale “event” escapes are typically caused by storms, vandalism, marine mammals, or human error.

Because storm damage is one of the greatest causes of escapes in southern bluefin tuna farms, the industry widely uses floating net pens constructed of high density polyethylene (HDPE) tubes that are designed for use in severe offshore weather conditions (Barneveld et al. 1997) (Clarke and Ham, 2008) (Tidwell 2012). Although aquaculture licensees are required to develop a strategy for minimizing the risk of escapes and to report escape events to PIRSA (Aquaculture Regulations 2005), only farm operators with hatchery-reared stock are obligated to fulfill these requirements. As discussed previously, the on-growing of hatchery-reared tuna is not currently practiced (or feasible) in the Australian bluefin tuna industry.

Without robust data on escape statistics, the magnitude of current escapes is unknown, and information on both low-level leakage and large event escapes is considered poor in Australia. Regardless of the absence of escape statistics, the relatively large biomass held in any one net pen and the risk of escape inherent in net pen farming suggests that the ongoing potential for escapes continues to be high.

Despite improvements in the design and construction of net pens, the risk of escape from catastrophic losses or chronic leakages undeniably remains. The initial numerical Escape Risk factor is scored 2 out of 10.

Recapture and Mortalities
With no specific recapture data available for Australia, no Recapture and Mortality adjustment was applied to the Escape Risk score (and will not affect the score for this criterion due to the wild-caught nature of the stocked bluefin).

Factor 6.1b. Invasiveness
Because farm stock consists entirely of wild individuals that are native to Australia, any significant impact of escaped bluefin tuna on other wild species, including wild counterparts, is unlikely. Although the potential exists for ecological impact from reintroducing these farmed tuna into their native habitat (e.g., potential pathogen amplification and dispersal, which are addressed in C7 Disease), this Invasiveness factor (6.1b) is specific to the primary species being farmed. Given that farmed tuna are the product of capture-based aquaculture and that captive tuna are native to Australian waters, escapees would pose no significant risk of direct, ecological impacts (i.e., competitive and/or genetic) upon their reintroduction. Furthermore, southern bluefin migrations primarily occur in deeper waters off the southern coast of Australia, but lower Spencer Gulf is within their native range and bluefin can be naturally found in these nearshore waters on an occasional basis (pers. comm., Anonymous 15). Consequently, the overall Invasiveness score for farmed southern bluefin tuna in Australia is 10 out of 10.

Escape Criterion—Conclusions and Final Score
Although the ongoing potential for southern bluefin tuna escapes from a high-risk production system are significant, invasive impacts are considered low for captured wild tuna that escape into their original environment. The final score for the Escape Criterion is 10 out of 10.

Criterion 7. Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

- *Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body*
- *Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Pathogen and parasite parameters	Score	
C7 Biosecurity	6.00	
C7 Disease; pathogen and parasite Final Score	**6.00**	**YELLOW**
Critical?	**NO**	

Brief Summary

Although southern bluefin tuna farms are strongly associated with high pathogen prevalence and diversity, disease-related mortality in Australia is generally low because of substantial fallow periods, low stocking densities, and the stocking of large immuno-competent tuna. Disease management training and best management protocols have been developed jointly by the tuna farming industry and government research campaigns. There is currently no clear evidence that pathogens or parasites within southern bluefin farms are causing significant population declines in wild tuna stocks, but the prevalence of pathogens within farm sites, the open nature of tuna net pens, and the proximity between farm sites to southern bluefin migration routes warrant a low to moderate level of ongoing concern for potential disease transfer between farmed and wild species. These conditions result in a precautionary Criterion 7 - Disease score of 6 out of 10.

Justification of Ranking

The open nature of tuna net pens means that farm fish are constantly exposed to ubiquitous pathogens from the surrounding waterbody, from wild fish, and from other captive individuals. As a result, tuna farms can act as a temporary reservoir for a variety of pathogens and parasites that have the potential to affect other wild species in the region.

In Australia, diseases in wild tuna are caused by a variety of pathogens including parasites, bacteria, and viruses (Nowak et al. 2003). Though infections occur at very low levels in the wild, an increase in the intensity and prevalence of infection for some of these pathogens has been observed in farmed southern bluefin (Nowak et al. 2003) (Aiken et al. 2006) (Aiken et al. 2007) (Nowak et al. 2007) (Hayward et al. 2010) (Hardy-Smith et al. 2012).

From 2001–2008, the Aquafin CRC Health Program conducted risk assessments of potential principal pathogens and other health threats associated with farmed southern bluefin (Aquafin

CRC Project 3.1 & 3.5). Data on these pathogens and their health impacts have expanded the industry's health management capability by providing a comprehensive assessment of potential health threats, monitoring tools, and pathogen-identification training (Aquafin CRC 2008).

Parasite prevalence and diversity

According to the literature, a diverse parasite community has been reported for farmed tuna (Deveney et al. 2005), in which parasites were present on farmed southern bluefin each year (Nowak et al. 2006). At least 30 parasite species spanning several phyla, including Acanthocephala, Arthropoda, Aschelminthes, Ciliophora, Myxozoa, and Platyhelminthes, have been identified in farmed southern bluefin (Nowak et al. 2003). Furthermore, southern bluefin tuna parasitofauna is primarily dominated by trematode flatworms (Table 2) (Nowak et al. 2003) (Ottolenghi 2004) (Deveney et al. 2005). For sea lice, over 99.5% of all parasites identified on farmed southern bluefin belonged to a single dominant species, *Caligus chiastos* (Hayward et al. 2010).

Table 2. Pathogens of bluefin tuna (Source: Ottolenghi 2004).

VIRUSES
Iridoviruses
→ Red seabream iridoviral (RSIV)
BACTERIA
→ *Aeromonas* sp.
→ *Caligus elongatus*
→ *Vibrio* spp.
→ *Photobacterium damsela* subsp. *Piscida*
→ *Mycobacterium marinum*
PARASITES
Protozoa
→ *Goussia auxidis*
→ *Uronema nigricans*
Myxosporea
→ *Kudoa clupeidae*
→ *Kudoa* sp.
Monogenea
→ *Benedenia seriolae*
→ *Caballerocotyla* sp.
→ *Hexostoma* sp.
→ *Metapseudaxine ventrosicula*
→ *Nasicola* sp.
→ *Neohexostoma* sp.
→ *Sibitrema poonui*
→ *Tristomella* sp.
Digenea
→ *Anaplerurus thynnusi*
→ *Aponurus lagunculus*
→ *Atalostropiom sardae*
→ *Bucephalopsis sibi*
→ *Cardicola* sp.
→ *Cetiotrema crassum*
→ *Celiotrema thynni*
→ *Colocyntotrema* sp.
→ *Didymocylindrus filiformis*
→ *Didymocystis* sp.
→ *Didymocystoides semiglobularis*
→ *Didyimoproblema fusiforme*
→ *Didymozoon* sp.
→ *Distomum clavatum*
→ *Hirudinella* sp.
→ *Koellikerioides orientalis*
→ *Köllikeria* sp.
→ *Lescithaster gibbosus*
→ *Lecithocladium excisum*
→ *Lobatozoum multisacculatum*
→ *Nematobothrium* sp.
→ *Oesophagocystis* sp.
→ *Prosorhynchoides sibi*
→ *Rhipdocotyle* sp.
→ *Sterrhurus imocavus*
→ *Syncoelium filiferum*
→ *Wedlia* sp.
Cestoda
→ *Callitetrarhynchus gracilis*
→ *Grillotia* sp.
→ *Lacistorhyncus tenuis*
→ *Nybelinia lingualis*
→ *Pelichnibothrium* sp.
→ *Tentacularia coryphaenae*
→ *Tetraphyllidean larvae*
Nematoda
→ *Anisakis* sp.
→ *Contracaecum* sp.
→ *Heptachona caudata*
→ *Hysterothylacium* sp.
→ *Oncophora melanocephala*
→ *Sprirurida*
Achantocephala
→ *Bolbosoma vasculosum*
→ *Neorhadinorhyncus nudus*
→ *Rhadinorhyncus pristis*
Copepoda
→ *Brachiella thynni*
→ *Caligus* sp.
→ *Euryiphorus brachypterus*
→ *Pennella filosa*
→ *Pseudocynus appendiculatus*

Interactions with wild teleosts

For capture-based aquaculture, most parasites in farms originate in the surrounding water, and therefore are of concern to surrounding populations when amplified. Studies indicate that the seasonal arrival of significant numbers of scavenging wild teleosts (specifically Degen's leatherjacket *[Thamnaconus degeni]*) to the TFZ is responsible for transmitting sea lice to farmed tuna (Hayward et al. 2008) (Hayward et al. 2009) (Hayward et al. 2010), (Hayward et al. 2011). In contrast with a decline in sea lice infections on farmed southern bluefin near harvest, there was a significant increase in prevalence and abundance of sea lice on Degen's leatherjacket over the farming period (Hayward et al. 2011). Although the reason for the decline in sea lice infections in farmed tuna are not known (Hayward et al. 2008), this opposing pattern of infection between farmed tuna and Degen's leatherjacket indicates that infected farmed bluefin are most likely not acting as reservoir hosts for wild leatherjackets (Hayward et al. 2011). Based on similar temporal patterns of parasite prevalence and intensity, other studies report that tuna are being infected by blood flukes post-capture, because infections were not detected in wild tuna upon initial capture (Aiken et al. 2006) (Nowak et al. 2007).

Epizootics

Epizootics of a range of different parasites have been documented among farmed southern bluefin, including sea lice on the skin and fins (primarily *Caligus chiastos*) (Hayward et al. 2008) (Hayward et al. 2009) and blood flukes (primarily *Cardicola forsteri*) in cardiac blood (Aiken et al. 2006) (Aiken et al. 2008) (Aiken et al. 2009) (Colquitt et al. 2001) (Cribb et al. 2000) (Hayward et al. 2010) (Dennis et al. 2011) (Kirchhoff et al. 2011). Although no epizootics of sea lice or blood flukes have been documented in other regions and countries farming bluefin tuna (i.e., Mediterranean, Japan, and Pacific Mexico) (Hayward et al. 2010), both species can reach a maximum prevalence rate of 100% over the course of several months in Australia (Cribb et al. 2000) (Colquitt et al. 2001) (Nowak et al. 2003) (Nowak 2004) (Aiken et al. 2006) (Aiken et al. 2007) (Aiken et al. 2008) (Aiken et al. 2009) (Nowak et al. 2007) (Hayward et al. 2010) (Dennis et al. 2011) (Kirchhoff et al. 2011). With both parasites producing significant pathology (Nowak et al. 2003), sea lice are associated with a significant reduction in the condition factor (a measure of overall health) in host southern bluefin (Nowak et al. 2007) (Hayward et al. 2008) (Hayward et al. 2009) (Hayward et al. 2010), and blood flukes were identified as one of the most significant health risks associated with Australian southern bluefin farms (Nowak 2004) (Nowak et al. 2007) (Kirchhoff et al. 2011). According to ASBTIA (pers. comm. 2015), the intermediate host for blood flukes has been identified, and the bluefin tuna farming industries in Australia and Japan have been working together on praziquantel treatments.

Lack of disease

Despite the strong prevalence and diversity of pathogens described in tuna farming, the large number of infectious species does not result in the intensive proliferation of disease (Nowak et al. 2007). Although a range of parasites has been identified in wild tuna, the southern bluefin tuna farming industry has experienced relatively few health problems or health-related mortalities throughout its history (Nowak et al. 2003) (Deveney et al. 2005) (Nowak et al. 2007) (Leef et al. 2012); none of the investigated parasites was directly linked to mortalities (Nowak et al. 2007). Aside from sea lice, no other parasites produced a reduced condition factor in farmed southern bluefin (Nowak et al. 2007) (Hayward et al. 2008) (Hayward et al. 2009) (Hayward et al. 2010). Furthermore, most didymozoid species are not considered pathogenic (Deveney et al. 2005) and a number of other tuna parasites, including a monogenean *(Hexostoma thynni)* and a copepod *(Euryphorus brachypterus)*, showed no evident epizootic patterns (Hayward et al. 2008b). This lack of disease amplification in southern bluefin farming has been attributed to substantial fallow periods, short rearing times, low stocking densities, and the stocking of immuno-competent tuna (Nowak et al. 2003) (Nowak 2004) (Deveney et al. 2005) (Nowak et al. 2007) (Hayward et al. 2007) (Padula et al. 2008) (Hardy Smith et al. 2012). Bluefin have been reported to be relatively resistant to bacterial infections, even when subjected to trauma and other factors that predispose them to infection (Nowak et al. 2003) (Ottolenghi 2004) (Nowak et al. 2007). Even though the Australian tuna farming industry has yet to be seriously affected by disease-related mortalities, further enlargement of the industry or the development of intensive hatchery production may increase the risk of health problems (Nowak et al. 2003) (Nowak et al. 2007) (pers. comm., ASBTIA 2015).

Risk of entry, establishment, and spread
Based on CRC Aquafin assessments of disease factors influencing farmed tuna, the health risks associated with southern bluefin pathogens are estimated to be low for overall tuna health (Nowak et al. 2003) (Nowak et al. 2007). In these assessments, the risks of entry, establishment, and proliferation of viruses (iridovirus), bacteria (mycobacteriosis), protozoans, and metazoans (Acanthocephala, Arthropoda, Aschelminthes, Myxozoa, and Platyhelminthes) are all either considered low, very low, or negligible (Nowak et al. 2003) (Nowak et al. 2007).

Introduced pathogens
The use of foreign baitfish as feed has a potential to be a vector for exotic pathogens. The globalized sourcing of whole feedfish for southern bluefin tuna farming potentially enables pathogenic microorganisms to infect and subsequently propagate diseases in farmed tuna, and local fish populations could suffer mortalities. Equally, the dissemination of a virus (via tuna feces, seagulls, or uneaten baitfish) into a foreign environment represents a serious threat to species with a naive immune response. A well-known example of this occurred in southern bluefin tuna farms in 1995 and 1998, in which a previously unknown pilchard herpes virus (PHV) was propagated by exotic baitfish feed, resulting in two mass mortality events that reduced the native Australian pilchard spawning biomass by 75% and 70%, respectively, though it has since recovered (Ward et al. 2007) (WWF 2005).

Despite the continued use of exotic baitfish to feed southern bluefin in Australia since the introduction of PHV, the introduction or reintroduction of foreign diseases into bluefin tuna farms or wild fish populations has yet to be repeated.

Disease management
Since the PHV outbreaks in 1995 and 1998, the southern bluefin tuna industry has had a history of excellent fish health status and very low mortalities. Aquafin CRC has provided health training to the industry through pathogen sampling protocols and basic diagnostic procedures, and best-practice protocols have been developed for the metazoan parasite (Nowak et al.

2007) (Clarke and Ham 2008). Through the Aquafin CRC program, all common southern bluefin tuna parasites have been identified and a baseline for parasite loads has been developed (Nowak et al. 2007).

Under Aquaculture Regulations 2005, infected farmed tuna may not be introduced or removed from the license area without prior approval, and licensees are required to report unusually high mortality events and to isolate unaffected stock.

Currently, praziquantel represents the only chemical therapeutant used in southern bluefin tuna farming, and it is used to treat blood fluke infections *(Cardicola forsteri)* (see Criterion 4 - Chemical Use for more information).

The SA government and the tuna farming industry are actively involved in a cooperative health program that documents and monitors the health of farmed tuna. In addition to an industry-wide monitoring program for parasites (Clarke and Ham 2008), an online health database (SBT Health) has also been developed to provide and record laboratory-related health information on farmed tuna, as well as an ongoing record of environmental data, images, and documents (http://www.sbthealth.com.au/). Furthermore, the implementation of an Industry Code of Practice (e.g., net pen maintenance, low stocking density, minimizing tuna stress) has been effective at further reducing disease-related mortalities (Nowak et al. 2007) (Thomas 2007) (Nowak et al. 2010).

Disease Criterion—Conclusions and Final Score

Overall, there is currently no clear evidence that pathogens or parasites within Australian southern bluefin tuna farms are causing significant population declines in wild counterparts. Although industry-wide best management practices and a strong monitoring and regulatory management regime are in place for disease prevention and control, the prevalence and diversity of pathogens found in bluefin tuna farms and the open nature of net pens lend to possible pathogen transmission between farmed tuna and the surrounding environment. Furthermore, the potential for introducing exotic pathogens from imported baitfish (though risk is reduced through implemented biosecurity measures) and consideration of the geographic proximity between the tuna farming industry and the migratory feeding routes of juvenile southern bluefin represent areas of concern for potential disease impacts.

Ultimately, data show low, temporary, or infrequent occurrences of on-farm infections or mortalities. Therefore, the final score for the Criterion 7 - Disease is 6 out of 10 and reflects the ongoing ecological risk associated with the potential for amplified pathogen transmission through open-exchange net pens.

Criterion 8. Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for on-growing to harvest size in farms*
- *Sustainability unit: wild fish populations*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstocks, use minimal numbers, or source them from demonstrably sustainable fisheries.*

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	0	
C8 Source of stock Final Score	**0.00**	**RED**

Brief Summary

Australian bluefin tuna farms are considered to be 100% reliant on critically endangered wild tuna populations due to the industry-wide dependence on wild-caught individuals for farm stock. Thus, the Criterion 8 - Source of Stock score is 0 out of 10.

Justification of Ranking

In Australia, farmed southern bluefin are produced exclusively using a culture method relying entirely on catching wild tuna, transporting them into net pens, and rearing them as farm stock (Cardia and Lovatelli 2007) (Clarke and Ham 2008) (Blinch et al. 2011) (Clean Seas Tuna 2014). The inherently extractive nature of southern bluefin farming is compounded by the exclusive use of juveniles that have not reached sexual maturity and are prevented from spawning and contributing to wild stock recruitment. The ongoing removal of endangered fish from the wild, whether for wild-capture fisheries or for farm production, results in the loss of ecosystem services provided by southern bluefin throughout its native range.

Although fully farm-raised Pacific bluefin tuna *(Thunnus orientalis)* are being produced in small numbers in Japan, the breeding of southern bluefin tuna from egg to adult has yet to be achieved on a commercial scale in Australia (Ottolenghi 2008) (Clean Seas Tuna 2014) (pers. comm., ASBTIA 2015). Breeding challenges include the length of time that southern bluefin require to reach sexual maturity, infrequency of spawning events, identifying which early feed ingredients to use, maintaining low bacterial levels, and that southern bluefin turn cannibalistic if left in pens with their young (Blinch et al. 2011). For these reasons, commercial tuna farms in Australia continue to rely completely on the capture of wild-caught juvenile southern bluefin tuna for use as captive farm stock.

In addition to government breeding programs, southern bluefin propagation has only been attempted by a single private South Australian company, Clean Seas Tuna Ltd., since 2000 (http://www.cleanseas.com.au/main/sbt-propagation-program.html). Although the production of larvae has been reported over a number of years (with some fish being raised to 30–40 cm in length) (Pecl et al. 2011), survival has remained inadequate for commercial-scale hatchery production for a range of economic and biological reasons (pers. comm., ASBTIA 2015). As of 2016, grow-out of commercial quantities of tuna fingerlings has been unsuccessful, and Clean Seas suspended its Tuna Propagation Research Program in 2013 and deferred further research to the Seafood CRC and FRDC (Clean Seas Tuna 2010) (Clean Seas Tuna 2014). As an inherent part of capture-based aquaculture, southern bluefin farming practices clearly overlap with the wild fisheries sector, and access to farm stock is heavily influenced by fisheries regulations and management.

Both regional fisheries management organizations (RFMO) and national fisheries agencies regulate bluefin tuna fisheries in Australia.

1. **Commission for the Conservation of Southern Bluefin Tuna (CCSBT)**
   CCSBT is an international organization that manages the southern bluefin tuna fishery throughout its global distribution. The CCSBT was formed under the Convention for the Conservation of Southern Bluefin Tuna 1994 and is primarily responsible for setting the total allowable catch (TAC) and allocating quotas for southern bluefin tuna among its member nations, authorizing bluefin farms and capture vessels, and implementing the Catch Documentation Scheme (CDS) to track domestic landings, transshipments, exports, and imports. Member nations are also required to tag each whole tuna, participate in a transshipment monitoring program (observer presence), and install a satellite-linked vessel monitoring system (VMS).

2. **Australian Fisheries Management Authority (AFMA)**
   To monitor bluefin catches, the AFMA requires the development of a stock register for each tuna farming company. The register records the total number of tuna being farmed, daily mortalities, and the number of tuna harvested. Each register is annually audited by AFMA and if there are differences between tuna inputs and outputs, these discrepancies are investigated by government inspectors (www.afma.gov.au).

Declining wild stocks

Commercial catches of southern bluefin tuna were very high in the early years of the fishery before declining steadily in the early 1950s (Flood et al. 2012). After catches peaked at 80,000 MT in the early 1960s (Cardia and Lovatelli 2007), unregulated increases in fishing effort for southern bluefin since the 1950s resulted in substantially reduced catches. Although dramatic cuts in catch limits were implemented in 1989 (Tanner 2007), by the late 1990s, southern bluefin stocks were at an all-time low, with population size at less than 9% of 1960 figures (Volpe 2005).

Beginning in the mid-1980s, the primary nations fishing the species at the time (Australia, Japan, and New Zealand) began to voluntarily apply quotas as a self-management tool to enable stocks to rebuild (Love and Langenkamp 2003). In 1994, these voluntary arrangements were formalized with the signing of the Convention for the Conservation of Southern Bluefin Tuna, and the CCSBT has since managed the fishery internationally. Despite the adoption of the CCSBT quota system, total global catches exceeded reported catches from 1985–2005, with some studies estimating unreported catches surpassing 178,000 MT over this period (Polacheck and Davies 2008) (Polacheck 2012). Furthermore, a review of Japanese market statistics in 2006 revealed that very substantial and continuous unreported catches of southern bluefin had been taken by longline vessels since at least the early 1990s (Polacheck 2012). From a peak catch of 21,000 MT in 1982, the Australian quota was reduced to 14,500 MT in 1988 and is currently set at 5,665 MT for 2015–2017 (Cardia and Lovatelli 2007) (Tanner and Volkman 2009) (CCSBT 2013b) (CCSBT 2014).

The most recent stock status assessments by the CCSBT (2011), ABARES (2014), and ISSF (2015) estimate that the biomass of the southern bluefin biological stock is at 3%–12% of the original spawning stock biomass (Figure 3) (CCSBT 2011) (Georgeson et al. 2014) (ISSF 2015). Currently, the southern bluefin biological stock is "recruitment-overfished" on a global scale, and stock size is well below target reference levels chosen by the CCSBT (Flood et al. 2012).

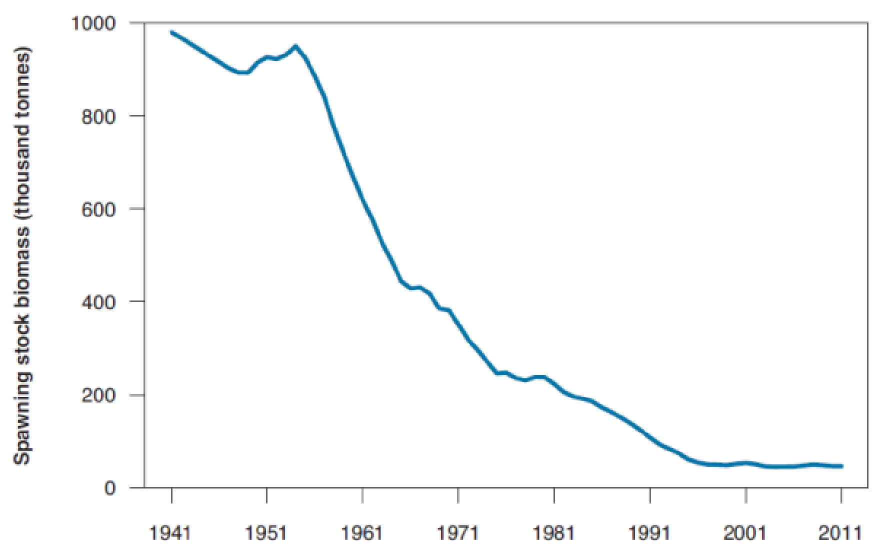

Figure 3. Global southern bluefin spawning stock biomass (Flood et al. 2012).

After decades of overfishing, southern bluefin tuna was listed as "Critically Endangered" under the IUCN's Red List in 1996 and 2009, as well as a "Conservation Dependent" species under Australia's Environment Protection and Biodiversity Conservation Act 1999 in 2010 (Collette et al. 2011) (Flood et al. 2012). In 2011, the CCSBT adopted a harvest control strategy, the Bali Management Procedure, which established global TAC guidelines to rebuild southern bluefin tuna stocks to 20% of the original spawning stock biomass with 70% probability by 2035 (CCSBT 2013). Because of the enactment of the Bali Management Procedure and subsequent changes in the TAC-setting process (precautionary Harvest Control Rule based on juvenile surveys and CPUE), recent trends in recruitment appear more positive than in previous assessments, but measurable improvements in spawning stock biomass have yet to be detected (Flood et al. 2012).

As of 2013, the total level of southern bluefin mortality from all sources (including releases/discards from the high seas longline fleets, recreational fishing catch, and unreported catches by non-members and members) is unknown and the stock is classified as Uncertain with regard to fishing mortality (Flood et al. 2012) (Georgeson et al. 2014). Furthermore, the reported 2013 global catch indicated that some Member States had exceeded their allocation (Georgeson et al. 2014). As of 2014, the spawning stock biomass of southern bluefin tuna remains at a very low level, so the stock remains classified as Overfished by the FRDC and ABARES. But the ISSF's most recent stock assessment indicates that overfishing is not occurring (ISSF 2015). Overall, there remains substantial uncertainty concerning the current levels of recovery and unaccounted catch mortality and their potential impact on stock rebuilding.

Source of Stock Criterion—Conclusions and Final Score

Because of the industry-wide use of wild-caught tuna as captive stock, the Australian southern bluefin tuna farming industry is considered to be fully reliant on wild bluefin tuna populations for its supply of fish. The ongoing removal of endangered fish, whether for fisheries or for farm production, is considered a significant loss of ecosystem services. Furthermore, the inherently extractive nature of southern bluefin farming is compounded by the exclusive use of juveniles that have not reached sexual maturity and are prevented from spawning and contributing to wild stock recruitment. These conditions result in a Criterion 8 - Source of Stock score of 0 out of 10.

Criterion 9X: Wildlife and predator mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**-5.00**	**YELLOW**
Critical?	NO	

Brief Summary

Seals, sharks, and dolphins are the primary wildlife species interacting with bluefin tuna farms in Australia. For seabirds and protected marine vertebrates, tuna farmers must employ non-lethal methods to deter predators, as required by national and state legislation. Although there are predator-interaction reporting obligations for tuna farmers, data have informed only a small number of interactions since 2005. Exceptionally little robust data exist on the tuna farming industry's impact on seal, sea lion, and shark populations, though mortalities associated with tuna farming are unlikely to cause population-level affects. The lack of statistical data available for farm-related wildlife mortalities, combined with the endangered status of shark and sea lion species, historic intentional killings, and the potential for interactions with these species to be underreported, result in a precautionary approach to scoring this criterion. The penalty score for Exceptional Criterion 9X - Wildlife Mortalities is –5 out of –10.

Justification of Ranking

Interactions between marine mammals and the tuna farming industry in South Australia were detected soon after establishment of the industry in the early 1990s, because net pens were found to act as fish aggregating devices (Fernandes et al. 2007). Although much of the information on marine mammal interactions is anecdotal (Tanner 2007) (National Seal Strategy Group and Stewardson 2007) (Goldsworthy et al. 2009), seals, sharks, and dolphins have all been reported as being entangled or enclosed and subsequently dying in active net pens (Kemper and Gibbs 2001) (Tanner 2007) (National Seal Strategy Group and Stewardson 2007).

Seals and sea lions

In Australia, numerous interactions occur between finfish farms and New Zealand fur seals *(Arctocephalus forsteri)* and Australian sea lions *(Neophoca cinerea)* (Tanner 2007). There are large colonies of both the Australian sea lion and the New Zealand fur seal in the Port Lincoln region, where finfish farms are within the foraging range of seal colonies (Goldsworthy et al.

2009). Anecdotal evidence suggests that pinniped interactions began about 4 years after tuna aquaculture began in 1991 (Kemper et al. 2003).

The coexistence of tuna aquaculture with large populations of both Australian sea lions and New Zealand fur seals provides the potential for entanglement in nets. The majority of the interactions with tuna net pens involve the Australian sea lion, with only occasional interactions involving juvenile New Zealand fur seals (Tanner 2007) (National Seal Strategy Group and Stewardson 2007) (Goldsworthy et al. 2009) (PIRSA 2013b). Although neither species is known to utilize tuna as a food source (Page et al. 2005) (McIntosh et al. 2006), sea lions were regularly observed entering net pens by jumping over the top of the floating pontoon rings and attacking farm stock (pers. comm., ASBTIA 2015).

The tuna farming industry has responded to seal and sea lion interactions by implementing improved net maintenance strategies and erecting physical barriers on the surface of the net pens to reduce the likelihood of pinnipeds gaining access to fish (Goldsworthy et al. 2009). The most important strategies currently used are high fences (35 m) (which may include a smaller electric fence), frequent and regular net maintenance (repairing holes and loose netting), net stiffening (well-tensioned heavy-gauge nets), regular removal of tuna mortalities from net pens, and reducing feed wastage (National Seal Strategy Group and Stewardson 2007) (Nowak et al. 2003) (Tanner 2007) (Goldsworthy et al. 2009) (pers. comm., Anonymous (b) 2015).

With regard to high seal fences, which are the primary restraining measure used in southern bluefin tuna farming, anecdotal reports suggest that the adoption of high seal fences across the industry (average 1.85 m in height) has proved to be effective in deterring pinnipeds since the late 1990s and has significantly reduced the potential for adverse interactions between tuna farms and seals and sea lions (Tanner 2007) (Goldsworthy et al. 2009). Although fatal entanglement of seals and sea lions in loose netting and illegal killing of seals and sea lions near finfish operations have been reported (National Seal Strategy Group and Stewardson 2007), predator mortalities have been significantly reduced due to these farm management improvements (Nowak et al. 2003) (National Seal Strategy Group and Stewardson 2007) (Tanner, 2007) (Clarke and Ham 2008) (Goldsworthy et al. 2009) (pers. comm., PIRSA 2015). In 2014, seal interactions were further reduced by increasing the height of seal fences to 3–4 m (pers. comm., ASBTIA 2015).

The primary government management tool in place to limit interactions between finfish aquaculture and pinnipeds is buffer zones. These restrictions stipulate that southern bluefin farms are prohibited within a 15-km radius for major Australian sea lion breeding colonies and within a 5-km radius for known haul-out sites (Tanner 2007) (Goldsworthy et al. 2009) (PIRSA 2013b). TFZ policies comply with these distances recommended by the Marine Mammal and Marine Protected Areas Aquaculture Working Group. In 2009, studies by SARDI considering the foraging habits and spatial movements of sea lions within the Lower Eyre Peninsula area did not indicate any serious interactions or tendencies of tracked sea lions to interact with tuna farms in the area (Goldsworthy et. al. 2009) (PIRSA 2013b).

Because there is no formal observer program, the true level of impact on seals and sea lions from tuna farms is unknown (Galaz and Maddalena 2004) (Tanner, 2007) (National Seal Strategy Group and Stewardson 2007) (Goldsworthy et al. 2009). Nonetheless, the potential risk of interactions between seals and southern bluefin farms has been assessed as "Low to Moderate" by Aquafin CRC (Nowak et al. 2003) (Tanner 2007), and there have been no official reports of entanglement since anti-predator nets were phased out in the mid-1990s (National Seal Strategy Group and Stewardson 2007).

Sharks

Because of the tuna farming industry's reliance on wild tuna, interactions with sharks have been reported during the towing process as well as at net pen sites (Galaz and Maddalena 2004) (Tanner 2007). Interactions are primarily with bronze whaler sharks (not protected; usually killed) and white sharks, which are protected and methods of releasing them alive have been developed (pers. comm., PIRSA 2015), when the presence of tuna mortalities in cages or net pens is the primary factor triggering interactions (Tanner 2007). Given that the industry is concentrated in an area frequently inhabited by sharks, and particularly white sharks, it is likely that interactions will continue to occur under current management regimes.

Because of the interactions between sharks and tuna farming and the low reproductive rate of sharks, the potential risk associated with shark and tuna farm interactions has been assessed as "Moderate" by Aquafin CRC (Nowak et al. 2003) (Tanner) (2007). But PIRSA has indicated that husbandry practices and methods to release sharks from pontoons have been improved, and interactions have become increasingly rare. Since the establishment of incident reporting in 2005, only a single adverse interaction with a protected shark species has been reported by tuna farm operators (pers. comm., PIRSA 2015).

Dolphins

With a number of species found in the Spencer Gulf region, the impact of tuna aquaculture on dolphins has been primarily through incidental entanglement in anti-predator nets (an outer net that extended to the seafloor and acted as a barrier to predators) (Tanner 2007). Given that anti-predator nets are no longer used by the tuna farming industry, other improvements such as reductions in feed wastage, decreased mortalities, and regular removal of uneaten feedfish have practically eliminated dolphin mortalities. As a result, the potential risk from interactions between dolphins and tuna farms has been assessed as "Low" by Aquafin CRC (Tanner, 2007).

Wildlife management

The Fisheries Management Act 2007 provides offense provisions for the taking, injuring, or harming of marine mammals, protected species, or aquatic resources of a protected species. Under the section 71(1)(a), a person must not kill, injure, or molest, or cause or permit the killing, injuring, or molestation of a marine mammal (PIRSA 2013b). Furthermore, seals are specifically protected under the National Parks and Wildlife Act 1972 and the Fisheries Act 1983. All seal species and white sharks are also protected under the national Environment Protection and Biodiversity Conservation Act.

All marine mammals and sharks have the potential to become entangled in nets or mooring lines. Southern bluefin farmers must take all reasonable and practical measures to minimize adverse interactions with marine mammals (Tanner 2007). To minimize adverse interactions with seabirds and large marine vertebrates, sections 19 and 20 of Aquaculture Regulations 2005 require all licensees to have an approved strategy for minimizing adverse interactions with marine mammals, and to report entanglement or entrapment of protected species (pers. comm., PIRSA 2015). Pinniped, shark, and dolphin interactions (species, date, time, location) must also be reported to PIRSA in annual EMP reports (Tanner 2007). Furthermore, risks posed by the aquaculture activity are assessed at the time of license application using the National Ecological Sustainable Development (ESD) framework (Fletcher et al. 2004) (PIRSA 2013b).

Established regulatory requirements require tuna farmers to report pinniped, shark, and dolphin interactions, but there is no formal observer program to provide industry oversight, and little data are available regarding the impact that southern bluefin farms are having on the population size of these predators. Despite research projects to investigate seal and shark interactions by PIRSA (pers. comm., PIRSA 2015), these studies primarily focus on the nature and extent of wildlife interactions with farm sites to enhance industry best practices. Overall, although mortalities appear to be limited, ongoing interactions continue to be reported by tuna farmers (pers. comm., Anonymous (b) 2015). Furthermore, white sharks and Australian sea lions are currently listed as “Endangered” by the IUCN, and impacts to both species populations are unknown. Given the evidence for unreported encounters and historic reports of industry workers shooting seals (National Seal Strategy Group and Stewardson 2007) (Goldsworthy et. al., 2009), ongoing concern remains about the population-level impact of bluefin tuna farming on these vulnerable species.

Wildlife and Predator Mortalities Criterion—Conclusions and Final Score

Overall, the potential risks associated with seal, shark, and dolphin interactions and southern bluefin tuna farms are considered “Low to Moderate,” “Moderate,” or “Low” by Aquafin CRC. Although improved husbandry practices have strongly reduced wildlife mortalities in recent years, the evidence for unreported encounters, historic reports of intentional killings, and the endangered status of some species result in a precautionary approach to scoring this exceptional criterion.

Note that this is an “exceptional” criterion and the scoring range is from 0 (no concern) to –10 (very high concern). The final score for this exceptional criterion is therefore a deduction of –5 out of –10.

Criterion 10X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species other than the principle farmed species unintentionally transported during live animal shipments.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score.

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	2.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Brief Summary

In Australian bluefin tuna farming, wild stocks are captured and transported to net pens within the same waterbody, so the unintentional introduction of non-native species does not occur. Generally there is risk associated with open exchange net pens, but the exclusive use of native tuna (0% reliance on international or trans-waterbody live animal shipments) results in a Criterion 10X - Escape of unintentionally introduced species final score of 0 out of –10.

Justification of Ranking

In Australia, southern bluefin tuna farming is a capture-based aquaculture practice that relies on wild stocks that are native to the region. Thus, the unintentional introduction of non-native species does not occur.

Factor 10Xa International or trans-waterbody live animal shipments

Southern bluefin tuna grown in Australian net pens are wild stocks native to the region. There is 0% of the industry reliant on international or trans-waterbody live animal shipments, resulting in a Factor 10Xa score of 10 out of 10.

With no international or trans-waterbody animal movements, Factor 10Xb is not applicable.

Escape of Introduced Species Criterion—Conclusions and Final Score

In Australia, southern bluefin tuna farming is a capture-based aquaculture practice that relies on wild stocks that are native to the region. As such, the unintentional introduction of non-native species does not occur, and the final score is 0 out of –10 for Criterion 10X - Escape of unintentionally introduced species.

Overall Recommendation

The overall recommendation is as follows:

The overall final score is the average of the individual criterion scores (after the two exceptional scores have been deducted from the total). The overall ranking is decided according to the final score, the number of Red criteria, and the number of critical scores as follows:

– **Best Choice** = Final score ≥6.6 AND no individual criteria are Red (i.e. <3.3)
– **Good Alternative** = Final score ≥3.3 AND <6.6, OR Final score ≥ 6.6 and there is one individual Red criterion.
– **Red** = Final score <3.3, OR there is more than one individual Red criterion, OR there is one or more Critical score.

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.39	YELLOW	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	9.00	GREEN	NO
C4 Chemicals	6.00	YELLOW	NO
C5 Feed	0.00	CRITICAL	YES
C6 Escapes	10.00	GREEN	NO
C7 Disease	6.00	YELLOW	NO
C8 Source	0.00	RED	
C9X Wildlife mortalities	–5.00	YELLOW	NO
C10X Introduced species escape	0.00	GREEN	
Total	**40.39**		
Final score	**5.05**		

OVERALL RANKING

Final Score	5.05
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES

FINAL RANK

RED

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Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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About Seafood Watch®

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch®'s sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[8] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

The following **guiding principles** illustrate the qualities that aquaculture must possess to be considered sustainable by the Seafood Watch program:

Seafood Watch will:

- Support data transparency and therefore aquaculture producers or industries that make information and data on production practices and their impacts available to relevant stakeholders.
- Promote aquaculture production that minimizes or avoids the discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.
- Promote aquaculture production at locations, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats without unreasonably penalizing historic habitat damage.
- Promote aquaculture production that by design, management or regulation avoids the use and discharge of chemicals toxic to aquatic life, and/or effectively controls the frequency, risk of environmental impact and risk to human health of their use
- Within the typically limited data availability, use understandable quantitative and relative indicators to recognize the global impacts of feed production and the efficiency of conversion of feed ingredients to farmed seafood.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild fish or shellfish populations through competition, habitat damage, genetic introgression, hybridization, spawning disruption, changes in trophic structure or other impacts associated with the escape of farmed fish or other unintentionally introduced species.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.
- Promote the use of eggs, larvae, or juvenile fish produced in hatcheries using domesticated broodstocks thereby avoiding the need for wild capture
- Recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving

362 "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates.

practices for some criteria may lead to more energy intensive production systems (e.g. promoting more energy-intensive closed recirculation systems)

Once a score and rank has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choice/Green: Buy first, they're well managed and caught or farmed in ways that cause little harm to habitats or other wildlife.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they're caught or farmed.

Avoid/Red: Don't buy, they're overfished or caught or farmed in ways that harm other marine life or the environment.

Appendix 1 – Data points and all scoring calculations

This is a condensed version of the criteria and scoring sheet to provide access to all data points and calculations. See the Seafood Watch Aquaculture Criteria document for a full explanation of the criteria, calculations and scores. Yellow cells represent data entry points.

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quali	Score (0-10)
Industry or production statistics	*Yes*	10	10
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Chemical use	Yes	10	10
Feed	Yes	7.5	7.5
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	10	10
Source of stock	Yes	10	10
Predators and wildlife	Yes	5	5
Other – (e.g. GHG emissions)	No	Not relevan	n/a
Total			**75**

C1 Data Final Score	8.333333333	GREEN

Criterion 2: Effluents

Effluent Rapid Assessment

C2 Effluent Final Score	**8.00**	**GREEN**

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	9

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Yes	1
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Yes	1
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Yes	1
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Yes	1
		5

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Yes	1
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Yes	1
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Yes	1
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	Mostly	0.75
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Yes	1
		4.75

F3.2 Score (2.2a*2.2b/2.5)	9.50

C3 Habitat Final Score	9.17	GREEN
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	8.00	
C4 Chemical Use Final Score	8.00	GREEN
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use
Factor 5.1a - Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	22.5
Fishmeal from by-products (%)	0
% FM	22.5
Fish oil inclusion level (%)	5
Fish oil from by-products (%)	0
% FO	5
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	12.5
FIFO fishmeal	12.50
FIFO fish oil	12.50
Greater of the 2 FIFO scores	12.50
FIFO Score	**0.00**

Factor 5.1b - Sustainability of the Source of Wild Fish (SSWF)

SSWF	-4
SSWF Factor	-5

F5.1 Wild Fish Use Score	**0.00**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	18.13
eFCR	12.5
Feed protein from NON-EDIBLE sources (%)	0
Feed protein from EDIBLE CROP soruces (%)	0
Protein OUTPUTS	
Protein content of whole harvested fish (%)	23
Edible yield of harvested fish (%)	58
Non-edible by-products from harvested fish used for other food production	50
Protein IN	226.63
Protein OUT	18.17
Net protein gain or loss (%)	-91.98235
Critical?	YES

F5.2 Net protein Score	0.00	

5.3. Feed Footprint

5.3a Ocean area of primary productivity appropriated by feed ingredients per ton of farmed seafood

Inclusion level of aquatic feed ingredients (%)	27.5
eFCR	12.5
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	89.40

5.3b Land area appropriated by feed ingredients per ton of production

Inclusion level of crop feed ingredients (%)	27.5
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingedients to land animal products	*2.88*
eFCR	12.5
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	1.30

Value (Ocean + Land Area)	90.70

F5.3 Feed Footprint Score	0.00

C5 Feed Final Score	0.00	RED
	Critical?	YES

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	2

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**2**

6.1b. Invasiveness

Part A – Native species

Score	5

Part B – Non-Native species

Score	0

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	No
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavi	No
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement o	No
Do escapees have some other impact on other native species or habitats?	No
	5

F 6.1b Score	**10**

Final C6 Score	**10.00**	**GREEN**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	6.00	
C7 Disease; pathogen and parasite Final Score	**6.00**	**YELLOW**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	0	
C8 Source of stock Final Score	**0**	**RED**

Criterion 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**-6.00**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	2.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Appendix 2 – Interim Update

An Interim Update of this assessment was conducted in February 2021. Interim Updates focus on an assessment's limiting (i.e. Critical or Red) criteria (inclusive of a review of the availability and quality of data relevant to those criteria), so this review evaluates Criterion 5 – Feed and Criterion 8x Source of Stock. No information was found or received that would suggest the final rating is no longer accurate. No edits were made to the text of the report (except an update note in the Executive Summary). The following text summarizes the findings of the review.

Criterion 1 – Data
The availability and quality of data for Southern bluefin tuna farmed in Australia in net pens is moderate overall. Data for Criterion 5 – Feed were captured from peer reviewed literature, although the most recent readily available publications documenting production practices and performance are from 2016. Data for Criterion 8x – Source of stock were readily available, however, there is a lack of a fishery assessment evaluating the potential ecological impacts of purse seine fisheries corralling wild juveniles for tuna ranching operations. As a result, the availability of information for each Criterion (e.g., Feed and Source of Stock) in this interim update is moderate.

Criterion 5 – Feed
In the 2016 SFW assessment of Australian net pen tuna aquaculture production, all Australian Pacific bluefin tuna (PBFT) farms applied whole fish as the exclusive feed source and there is no readily available evidence in primary literature or other sources that demonstrate feed practices have changed. The motivation to use whole fish instead of a pelleted diet are many fold, but briefly: (i) fish are less expensive than formulated diets, but still accounts for "over 60% of operation budgets for tuna farming operations" (Benetti et al 2016a), (ii) capturing wild tuna and weaning off whole fish to formulated pelleted feeds has led to increased mortality and quality issues - effecting demand from the Japanese market (Buentello et al., 2016a), and (iii) a preference for tuna with high fat content and flesh composition (Buentello et al., 2016a) that is achieved more easily with whole fish.

Due to these feeding practices, the "daily feeding of large quantities of untreated fresh or frozen fish/ squid results in unreasonably high feed conversion rates (22.6:1 to 17.8:1; Ottolenghi et al., 2004; Estess et al., 2014)." (Buentello et al., 2016a). This is consistent with the previous 2016 assessment of Australian net pen tuna farming practices, which estimated an eFCR of 12.5:1. Without a significant change in feeding practices by the industry, such as the use of pelleted feeds, it is highly unlikely for the eFCR to have changed significantly. Buentello et al (2016b) lays out the research needs to begin using pelleted feeds across the industry:

> *"For the foreseeable future, tuna nutrition will follow the path paved already for other marine fish such as the Atlantic salmon in the determination of nutrient requirements, utilization of alternative feed ingredients and supplements, and optimization of weaning and grow-out diets, taking into account the unique scombrid physiology and metabolic needs. The achievement of these nutritional objectives will resolve some of the most critical issues currently limiting the success and permanence of the tuna aquaculture industry."* (Buentello et al 2016b).

In the Seafood Watch Standard for Aquaculture, Criterion 5 – Feed, evaluates the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation. If the eFCR is ≥4, then the Feed criterion will be ‘Critical’. Currently, there is no evidence that the tuna industry has significantly substituted whole fish with pelleted feed. Since feeding practices haven’t changed, the eFCR is not likely to have significantly changed in response, and the eFCR reported in the 2016 assessment is highly likely to be still applicable. Therefore, the Feed Criterion score is still ‘Critical’ for tuna net pen operations in Australia.

Criterion 8x – Source of Stock

Closing the life cycle of Pacific Bluefin Tuna by developing a successful broodstock, hatchery, grow out to harvest tuna production cycle is a significant research and investment priority for the industry. Currently, Australia, Japan, and Mexico are all at different stages of commercializing these production techniques. In 2000, Australia’s Clean Seas Tuna Ltd “set the major objective to realize the commercial production of SBFT fingerlings from eggs spawned by captive broodstock” (Chen et al 2016), but after years of research and development Clean Seas Tuna Ltd shifted its focus from SBFT production in 2014 and is no longer actively developing SBFT hatchery production (Clean Seas, 2020). Mexico has no hatchery operations currently operating (Benetti et al 2016), but as of 2019 Ichthus Unlimited has begun pursuing fully closed life cycle production. Ichthus Unlimited is operating in San Diego, California, U.S.A close to the U.S-Mexico border with the goal of stocking PBFT for grow out in Mexico, and potentially the U.S. if demand arises (Leschin-Hoar, C., 2020). Japanese hatchery production of PBFT is further along with current egg to harvest production estimates around 6.5% of total PBFT aquaculture production in Japan (Craze and Waycott, 2020).

Since there are no known operating hatcheries in Australia producing SBFT, all of the SBFT farmed in Australia are sourced from wild SBFT stock; a practice of aquaculture described as ranching – the practice of corralling adults for grow out or broodstock. In Australia, 95% of Australia’s Southern Bluefin Tuna quota are caught between December and March by purse seiners:

> “Spotting aircraft direct chum vessels to schools of SBFT observed from the air. To lead SBFT schools close to vessels towing specialized pontoons, deckhands on the chum vessel cast thawed and live local baitfish (Sardinops sagax) into the water. Once the school of SBFT is in close proximity to the towing pontoon, a commercial purse-seine vessel encircles the chum vessel and the SBFT school with a purse-seine net measuring 1000 m long by 130 m deep. The purse-seine vessel then retrieves the purse cable that runs along the bottom of the net containing the chum vessel and SBFT school in a net “bowl”. Before the purse-seine net is hauled in, the chum vessel leaves the net enclosure. Smaller vessels powered by outboard engines help to keep the purse-seine net open while it is hauled and at the same time the towing pontoon is moved to meet the purse-seine net containing the SBFT.” (Ellis and Kiessling, 2016).

The captured fish are ultimately destined for ranching operations off the coast of South Australia and harvested around June/July (OceanWatch Australia, 2021). This form of tuna ranching is the exclusive source for Australia’s SBFT production (Cardia and Lovatelli 2007; Clarke and Ham 2008; Blinch et al. 2011; AFMA, 2020; OceanWatch Australia, 2021).

The abundance of these wild populations and impacts of the fishery activities to ocean ecosystems is important to evaluate the sustainability of the industry. Australia’s government lists the conservation status for the Southern Bluefin Tuna as Conservation Dependent under the EPBC Act and the population is overfished (AFMA, 2020). The SBFT stock is considered recovering with current fishing mortalities set at a low concern as defined by a SFW assessment of Australia's drifting and long line fishery (SFW, 2020). However, a fishery assessment examining the practices used to corral wild SBFT stock is not available. Therefore, in the absence of a fishery assessment, which considers additional metrics (in addition to abundance and mortality; see Seafood Watch Standard for Fisheries) a precautionary approach of relying on the population abundance is used to inform Criterion 8x – Source of stock.

In the Seafood Watch Standard for Aquaculture, Criterion 8x evaluates the source of farm stock and its independence from wild stocks. Seafood Watch considers capturing wild fish, even from a sustainable fishery, and raising them on a farm to be a net loss of resources and ecosystem services. A score of 'Critical' is assigned if there is sourcing of wild juveniles and/or broodstock that are considered endangered, protected, vulnerable, threatened, or critically endangered by the IUCN Red List or by a national or other official list with equivalent categories. Since SBFT are considered overfished by the Australian government, the score for Criterion 8x is Critical for all Australian SBFT production.

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